Climate Change: Scottish Implications Scoping Study

SCOTTISH EXECUTIVE
Central Research Unit

CLIMATE CHANGE: SCOTTISH IMPLICATIONS SCOPING STUDY

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LIST OF ABBREVIATIONS

ABI	Association of British Insurers
ACBE	Advisory Committee on Business and the Environment
ATM	Auto-Teller Machine
BRE	Building Research Establishment
CAP	Common Agricultural Policy
CCIRG	Climate Change Impacts Review Group
CHP	Combined Heat and Power
COP	Conference of the Parties to the Convention
DETR	Department of Transport, Environment and the Regions
DoE	Department of the Environment
DTI	Department of Trade and Industry
EC	European Community
EU	European Union
FRS	Fisheries Research Services
GCM	General Circulation Model
GHGs	Greenhouse Gas
HMSO	Her Majesty's Stationery Office
ICT	Information and Communications Technology
IPCC	Intergovernmental Panel on Climate Change
IPPC	Integrated Pollution Prevention and Control
LA	Local Authority
LEEP	Lothian and Edinburgh Environmental Partnership
LFA	Less Favoured Area
MAFF	Ministry of Agriculture, Fisheries and Food
MLURI	Macaulay Land Use Research Institute
MtC	million tonnes carbon equivalent
MW	Megawatts
NHER	National Home Energy Rating
NI	National Insurance
NIWT	National Inventory of Woodland and Trees
NPPG	National Planning Policy Guideline
OD	Ordnance datum
OFFER	Office of Electricity Regulation
SEPA	Scottish Environment Protection Agency
SMEs	Small and medium-sized enterprises
SNH	Scottish Natural Heritage
SNIFFER	Scotland and Northern Ireland Forum for Environmental Research
SO	Scottish Office
SRO	Scottish Renewables Order
SSSI	Site of Special Scientific Interest
STB	Scottish Tourist Board
TWh	Tera Watt Hour
UKCIP	UK Climate Impacts Programme
UKOOA	UK Offshore Operators Association
VOC	Volatile Organic Compounds

EXECUTIVE SUMMARY

INTRODUCTION

1. Climate Change is caused by the emission of greenhouse gases. It has wide ranging implications for people, the economy, and the natural and built environment in Scotland, and is caused by greenhouse gas emissions. This Study was commissioned to gain a clearer understanding of the implications of climate change in Scotland. The research will also inform the development of a Scottish strategy to combat the impacts of climate change and introduce measures to reduce greenhouse gas emissions.

1. The study comprised three parts.
   - Identifying the key stakeholders and reviewing existing information concerning climate change issues within Scotland.
   - Interviewing experts from a wide range of public and private organisations affected by climate change issues.
   - Synthesising this expert knowledge into an analysis of the Scottish implications of climate change, together with an assessment of the implications for future work.

CLIMATE CHANGE ISSUES

2. Climate change will have direct and indirect impacts: direct impacts through changes in the physical environment or in the cost of adapting to change, and indirect impacts from the changes in society required to reduce emissions of greenhouse gases. These direct or indirect impacts may be beneficial, neutral or detrimental to different sectors within Scotland.

Direct impacts

3. The UK Climate Impacts Programme climate scenarios suggest that:
   - Over the next century, Scotland will become warmer. Average temperatures are likely to rise by between 1.2 to 2.6°C, with relatively more warming in winter than summer.
   - Annual precipitation is likely to increase by between 5 and 20 per cent by the end of the next century, with autumn and winter seeing the biggest increases. In contrast, spring amounts will be lower and there will be little change in summer.
   - The intensity of rainfall events is likely to increase, leading to increased risk of flooding.
   - There may be an increase in the frequency of very severe gales but a decrease in the number of gales overall.
   - The water balance is likely to remain favourable.
   - Direct short-wave solar radiation is likely to reduce over the next century as a result of increased cloud cover

The natural variability of the climate makes it difficult to attach high levels of significance to some of these suggested changes and further work is required. As well as these general trends, there are two possible 'climate surprises': the collapse of the ocean circulation in the North Atlantic - with dramatic consequences for European climate, and the collapse of the West Antarctic ice sheet, which would increase the rate and magnitude of sea level rise.

4. The climate scenarios are based on a coarse model grid, which does not resolve the complex landscape or variations of climate within Scotland (e.g. the trend for wetter weather in the west and drier areas in the east). Work is in hand through the UK Climate Impacts Programme and elsewhere to improve the resolution and accuracy of such climate scenarios.

5. As well as these national climate impacts, Scotland will be affected by the impact of climate change on other countries. For example, the regional pattern of water resources will change, adding further stress to existing political and economic issues. At present, projections of regional climate change and its resulting impacts are full of uncertainties. This international dimension to climate change provides both business opportunities and potential risks for Scotland.

Indirect impacts

6. Emissions of greenhouse gases are the prime human influence on the climate and must be reduced to minimise human-induced climate change. Under the Kyoto Protocol and European Union agreements, by 2008-2012 the UK must reduce its baseline emissions of a basket of 6 greenhouse gases by 12.5% from a baseline in 1990. In addition, the UK Government has set a domestic target to reduce carbon-dioxide emissions to 20% beneath the baseline. Actions to attain the Kyoto Protocol target must be equitably spread across the UK. The devolution legislation therefore includes powers that could be used to ensure that the devolved administrations contribute to the UK's target through action in policy areas for which they are responsible.

7. The Chancellor's recent announcement of a potentially controversial climate change levy on energy consumption, to be introduced in 2001, is the most far-reaching climate change policy to date. Other possible policy measures reflect the balance between use of taxation, regulations of emissions, emissions trading schemes and financial incentives.

IMPLICATIONS OF CLIMATE CHANGE

Energy

8. The market is the driving force in the energy sector, coupled with tight regulation to protect the public interest. Climate change is one uncertainty of many in this fast changing industry.

9. Strategies for reducing greenhouse gas emissions - beginning with the climate change levy in 2001 - are likely to have a more profound effect here than any direct impact of climate change. The options for reducing emissions from the energy supply sector depend on the changing mix of fuel used in generation, regulating emissions from and efficiencies of power stations, and the further development by companies of energy services for customers. Those questioned in the study sought a clear understanding of the future direction of Government policies concerned with the reduction of greenhouse gas emissions.

10. As the climate changes, this sector becomes vulnerable to sea level rise at coastal installations; storm damage and flooding associated with intense precipitation events. Existing structures are built to withstand extreme weather and, in the case of Nuclear Power,

must undergo periodic safety reviews of the structural integrity of their installations. The planning horizon in the industry is well over 20 years (and more for nuclear power stations), which suggests that the sector is in a good position to develop adaptive strategies as better information on climate impacts becomes available.

Transport

11. The key forces for change in the transport sector are: increasing the effectiveness of transport systems and reducing congestion and air pollution. These goals have considerable overlap with the needs of reducing greenhouse gas emissions.

12. Climate change impacts also present an important business risk to the transport sector. In particular, flooding and storms are serious detrimental impacts for land transport; while storms and, to a lesser extent, sea-level rise will impact on marine operations. Improved information on the effect of climate change on storm frequency is vital for the sector. The design of transport infrastructure has a long lead-time, which suggests that information on future climate change impacts should be an important element of the planning process.

Domestic

13. Numerous interwoven factors such as poor housing stock, fuel poverty, public health, and energy efficiency will drive change in the domestic sector.

14. Nevertheless, the means of reducing emissions from the domestic sector include tackling poor thermal efficiency of housing and reducing energy use by enforcing energy efficiency standards for domestic appliances. Such goals are identical to those seeking to improve the quality of housing stock and minimise problems such as fuel poverty. It appears that mutually beneficial policies are possible which tackle both the goal of improving the housing stock in Scotland and minimising emissions of greenhouse gases.

15. The changing climate will have an adverse effect on some dwellings, particularly if exposed to increased driving rain, storminess, or flooding. Future planning of housing would beneficially include an assessment of the risks of climate impacts. Respondents to this study suggested that closer co-ordination between insurers, planners and the Scottish Environment Protection Agency would be beneficial. There is a need for better information about the climate-related risks relating to different geographical zones.

Public Services

16. The key drivers in the public services concern the provision of a diverse range of services to the population under the competing demands of expectation and tight budgets.

17. The Water Authorities operate under tight European and UK regulation. Their reliance on surface water, and the time-scale needed for changes to infrastructure ensure that changing precipitation patterns is an important issue. For local authorities and public health, there are numerous competing claims on resources and existing financial structure militate against a proactive approach to climate change.

18. The major detrimental impacts of climate change are likely to be associated with flooding and storms, which disrupt the provision of services. Positive impacts from warmer

temperatures may include increased use of shared public space such as parks, which is recognised as being important for sustainable urban centres. For public health, secondary effects of climate change may result in increased air pollution and a higher incidence of respiratory diseases associated with damp However, positive impacts from warmer temperatures may include benefits to the forestry and agriculture industries; a reduction in cold-related deaths; and the feel-good factor associated with warmer climates. There is a need for better information about climate impacts in the public services.

Business

19. The vulnerabilities of business to climate impacts depend on the specific operation. The service industry, which contributes nearly two thirds of Scottish GDP is, in general, less sensitive than other businesses to the direct impacts of climate change; the key issues are impacts of temperature, rainfall and wind upon buildings. Indirectly, climate change might be more significant through changing structures of market demand for goods.

20. Of far greater concern to the study respondents was the impact of climate mitigation measures, such as the forthcoming climate change levy. Respondents saw other possible measures, such as carbon trading schemes, as being more in accord with the entrepreneurial spirit of commerce, though complications in its implementation remain. This study revealed a variety of views over the appropriate balance of measures, such as financial incentives, voluntary schemes and regulation.

Agriculture, forestry and fisheries

21. The management of resources of Scotland's natural environment is perhaps the sector most affected by climate change issues. Land use plays a key role in greenhouse gas emissions from the natural environment. Changed agricultural practices, such as increasing Set Aside land, or further afforestation, are relatively more important for greenhouse gas emissions in Scotland than in the UK.

22. Climate impacts are likely to be predominantly beneficial to forestry, through increased growth rates, the potential for increased biomass fuel usage and use of afforestation as part of an emissions mitigation strategy. Changes to subsidy, which drives changes in agriculture, are more important than direct climate impacts, but more diverse and valuable crops may be grown in future. There is compelling evidence that recent declines in both migratory salmon and some marine species may be linked to fundamental changes in ocean circulation around Scotland. Further work and improved data is a priority.

CROSS-CUTTING THEMES OF CLIMATE CHANGE

23. Climate is not the primary driver of change in any sector. The changes outlined by the climate scenarios, though they may pose serious commercial or practical risks to parts of some sectors, are unlikely to change this situation. For many sectors, more specific information is required about climate change impacts before they will influence strategic decisions.

24. In contrast, strategies to reduce greenhouse gas emissions have a direct impact on key drivers in most sectors, for example tax, legislation, energy efficiency and pollution control.

The implementation of emissions strategies begins in 2001 with the introduction of the climate change levy. The time-scales for detrimental physical impacts in Scotland is generally much longer than this. It is clear that there is a distinct gap between the financial impact of emissions reduction strategies and the observance of a changed climate.

25. This gap between the imminent costs of emission reduction and the much longer-term impacts of climate change could generate difficulties with respect to public perceptions. Shouldering significant cost burdens and implementing behaviour changes well in advance of, or indeed in the absence of, climate change impacts will be a difficult political burden. Therefore, the use of mechanisms to re-cycle revenue within sectors, such as transport, is likely to be increasingly important. Awareness of climate change issues is likely to rise as emissions strategies impact on financial decision-making.

26. The link between the drivers of change in different sectors and forthcoming emissions strategies also points to mutually beneficial 'win-win' situations. These occur when the driving changes in a sector force a reduction in emissions without a specific intention for doing so. Examples include:

- Improving the quality of housing stock will improve their thermal qualities and state of repair, which both reduces emissions and minimises the direct impacts of climate change, in addition to improving health and enhancing social inclusion
- Solving transport congestion and pollution, by more integrated social and transport planning, reduces emissions and may improve the capacity of the transport system and domestic sector to cope with adverse impacts
- Growth in the forestry industry provides opportunities of linkages with rural policies on jobs, commercial benefits from biomass fuel and wooden buildings, increased leisure opportunities and opportunities to contribute to Common Agricultural Policy reform, and the potential for carbon sequestration.

OPTIONS FOR FUTURE WORK

28. This scoping study suggests that there are two priorities for future work. The first is the clear need for higher resolution climate data and impact studies in Scotland. This requires work through both the UK Climate Impacts Programme, on improved climate scenarios, and by the initiation or integration of baseline studies of climate change in Scotland:

- A project funded by the Scottish and Northern Ireland Forum for Environmental Research (SNIFFER) has already been established to develop temperature indices for Scotland and Northern Ireland.
- The recently published set of climate change indicators for the UK should be evaluated for their relevance to Scotland.
- The creation of a 'meta-data' depository, which identifies climate data held by different organisations, would be a useful tool for climate impact assessments. This information needs to include key indicators of climate that are of interest to users, such as an index of storminess and of rainfall intensity.
- Maps are required of the exposure of geographical areas to future climate impacts, such as flooding, storminess and sea-level rise
- Data of changing patterns of precipitation and snowfall across Scotland are vital, along with improved modelling of future changes

- A full analysis of the relative impact of climate change on different regions of Scotland
- A comparison of expected climate impacts and planned mitigation and adaptation strategies with similar countries, such as Norway,Sweden and Ireland.

29. The second priority is for exploring the linkages between the main driving forces on each sector, the likely impacts of emissions strategies, and climate impacts. Climate impacts are not the most important driver on any one sector and are unlikely to become so in future. Effective adaptation to climate change requires identification of potential 'win-win' situations where emissions reductions and/or means of adapting to climate impacts occur in conjunction with policies affecting the drivers of change in the sector. This requires more information on:

- Public perceptions of climate change issues and uptake of measures to reduce greenhouse gas emissions prior to visible signs of detrimental climate impacts
- Effect of land use strategies, such as afforestation, on Scotland's greenhouse gas emissions
- Links between likely future changes in different sectors and the requirements of the sector to reduce greenhouse gas emissions
- Business opportunities associated with climate change issues

CHAPTER ONE INTRODUCTION

AIMS OF THE REPORT

1.1 This report is a scoping study to provide policy makers with information to guide their work in developing a future Scottish strategy for responding to climate change. Specifically, this report seeks to:

- identify the organisations and groups in Scotland affected by climate change
- assess the quality and scope of predicted impacts of climate change in Scotland
- review the existing understanding of and work on climate change in Scotland
- identify 'knowledge gaps' where further work is required on climate change issues

THE SCOPING STUDY IN CONTEXT

1.2 Climate change presents the decision-maker with a setof formidable complications, including inherent uncertainty, the potential for irreversible damages or costs, and long planning horizons with lengthy time-lags between actions and their effects. Appropriate decision-making requires disentangling the intricate links between climate, the natural environment and society. The last 20 years has seen a concerted attempt, both nationally and internationally, to develop the necessary knowledge to tackle climate change.

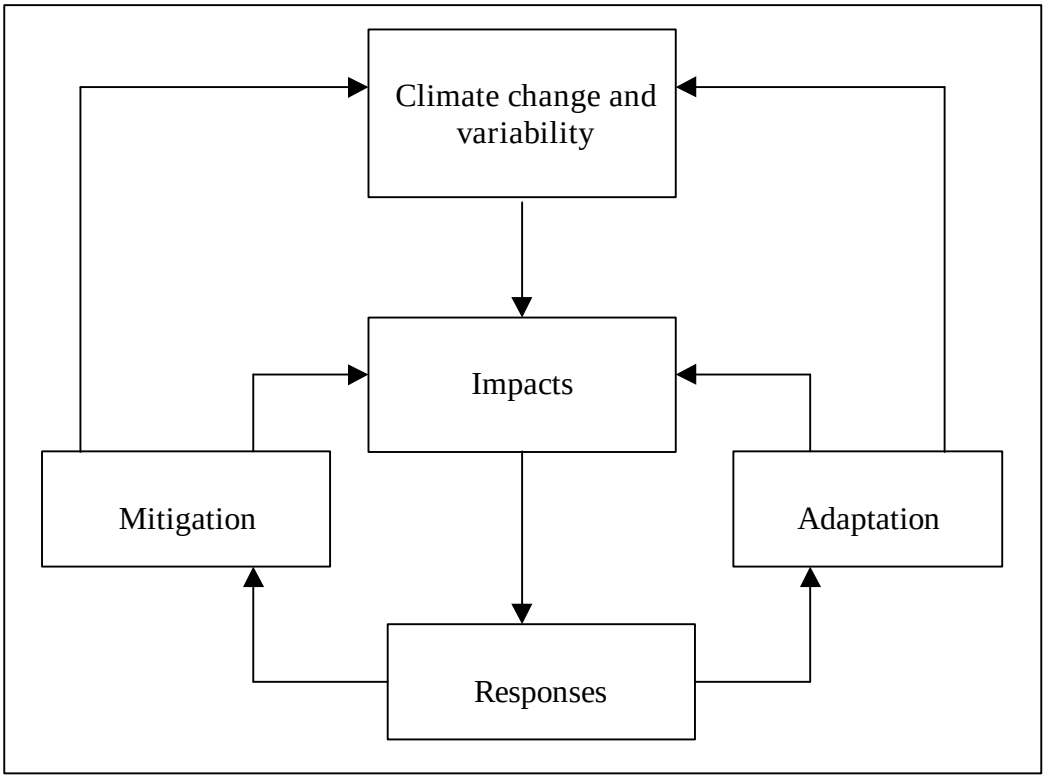
1.3 The first world climate conference was organised in 1979, since when there has been a proliferation of organisations and meetings dedicated to climate change. The Intergovernmental Panel on Climate Change (IPCC), established in 1988 by the United Nations Environment Programme and the World Meteorological Organisation, has driven understanding of global climate change over the past decade. It released its First Assessment Report in 1990, which galvanised policy makers and provided the basis for negotiations on the United Nations Framework Convention on Climate Change. This Convention was signed in 1992 at Rio de Janeiro and came into force in 1994. Subsequently, the Conference of the Parties to the Convention (COP) became the Convention's ultimate authority.

1.4 The IPCC adopted its Second Assessment Report in 1995 and concluded that: "the balance of evidence suggests there is a discernible human influence on global climate". The Report also reviewed information on the technical and economic feasibility of a range of potential measures for adapting to climate change and mitigating greenhouse gas emissions. It was clear that while climate change is a global issue, and requires a global response, determining appropriate national or regional climate strategies required a better understanding of local factors. The IPCC continues to provide scientific, technical and socio-economic advice through periodic assessment reports on the state of knowledge of causes of climate change, its potential impacts and options for response strategies. Its Third Assessment Report is currently in preparation.

1.5 The work of the IPCC reflects the key climate change issues facing society. The first is concerned with the direct impact of, and appropriate means of adapting to, climate change. The global climate system can exhibit long time-lags between cause and effect, so climate impacts resulting from past or existing actions by society may only become apparent after

many decades. These direct climate impacts may be beneficial, neutral or detrimental to society and the natural environment. While much recent research has focused on climate impacts, relatively little work has been conducted to date on the issue of adaptation to climate change. The second climate change issue concerns the impact on society resulting from policies to mitigate human-induced climate change. Emissions of greenhouse gases are the prime human influence on the climate and must be reduced to minimise human-induced climate change. The UK Government is required to meet international obligations for reducing greenhouse gas emissions, of which carbon dioxide is the most important. As with direct climate impacts, policies to reduce emissions may have positive, neutral or negative impacts on the economy. Below, we briefly review recent developments in climate impacts, climate change mitigation strategies and adaptation to climate change (see Figure 1.1).

Figure 1.1: The links between climate impacts, adaptation and mitigation



Note: Solid arrows indicate direct effects or feedbacks; dotted arrows depict secondary or indirect effects.
Source: Parry and Carter (1998)

Climate Impacts

1.6 Work to improve understanding of local and regional climate impacts in the UK was led by the UK Climate Change Impacts Review Group (CCIRG). Its 1996 report, entitled 'Review of the Potential Effects of Climate Change in the UK', for the then Department of the Environment (DoE) provides a useful baseline study on which to build future climate impacts studies. The DoE also commissioned a report to gain some insight to the sensitivity of the UK economy to climate variability and change, entitled 'Economic Impacts of the Hot Summer and Unusually Warm Year of 1995'. This latter report concluded that the UK economy is sensitive to climatic variations. It described both positive and negative impacts in different sectors and noted changes in the sensitivity of the economy to climate over time.

1.7 In 1997 the Department of Environment, Transport and the Regions (DETR) established the UK Climate Impacts Programme (UKCIP). This Programme provides an umbrella organisation to oversee and facilitate integration of the numerous recent and on-going sectoral and regional studies of climate change impacts in the UK (Table 1.1). Underpinning the UKCIP is the development of climate change scenarios for the UK by the Climate Research Unit at the University of East Anglia, published in 1998, and socio-economic scenarios or 'story-lines' being developed by the Science Policy Research Unit at Sussex University in 1999. The former work provides an in-depth analysis of possible future changes to UK climate over the next 100 years, while the latter aims to develop socio-economic scenarios for use in climate change assessments. This study is amongst the first to be conducted using the UKCIP climate scenarios. The DETR has also just published a set of 34 indicators of climate change and its impacts for the UK.

Table 1.1: Climate impacts projects currently under the UKCIP umbrella

Category	Project	Lead Contact	Expected Finish
Sub-UK scoping studies	Scotland	Andrew Kerr (CECS)	1999
	Wales	Havard Prosser (Welsh Office)	2000
Regional scoping studies	North West England	Simon Shackley (UMIST)	Completed
	RegIS (East Anglia and the North West): integrated assessment	Peter Love (SSLRC)	2000
	South East scoping study	Steven Wade (WS Atkins Water)	1999
	South West conference	Michael Galsworthy (IPE)	N/A
UK-wide sectoral assessments	Biodiversity review (DETR WCD)	Jo Hossell (ADAS)	2000
	Impacts on biodiversity	Mike Harley (English Nature)	tba
	Health	Bob Maynard	2000
	Insurance	Alistair Kinley (ABI)	tba
UKCIP	Socio-economic scenarios	Frans Berkhout (SPRU)	1999

Climate Change Mitigation

1.8 Concurrent with the national activities on climate impacts, meetings of the Conference of the Parties (COP) to the UN Climate Change Convention concentrated on achieving global agreements for reducing greenhouse gas emissions. The third COP meeting (COP-3) at Kyoto in 1997 led to the adoption of the Kyoto Protocol, under which industrialised countries have legally binding targets for reducing greenhouse gas emissions below 1990 levels by 2008-2012. The UK must reduce its baseline emissions of a basket of 6 greenhouse gases in 1990 of 216 MtC (million tonnes carbon equivalent) to 189 MtC per annum averaged over 2008-2012. In addition, the UK Government has set a domestic target to reduce carbon-dioxide emissions to 20% beneath the baseline. Details of the implementation of the Kyoto Protocol were considered further at the COP-4 meeting in Buenos Aires in 1998, but much remains to be determined.

1.9 The UK Government responded to the Kyoto Protocol by producing the 'UK Climate Change Programme: Consultation Paper', to stimulatedebate on how the UK might meet its Kyoto and Buenos Aires targets and the UK Government's domestic target (Tables 1.2 and 1.3). The consultation process, which was completed in February 1999, will inform the development of more concrete proposals on measures to mitigate greenhouse gas emissions. Actions to attain the Kyoto Protocol target must be equitably spread across the UK. The devolution legislation therefore includes powers that could be used to ensure that the devolved administrations contribute to the UK's target through action in policy areas for which they are responsible. The DETR prepares the annual UK greenhouse gas Emissions Inventory and has initiated a scoping study to study how the inventory could be disaggregated to areas of Scotland, England, Wales and Northern Ireland.

Table 1.2: Greenhouse gases and their relative contributions to UK emissions

Gas	Abbreviation	Sources	% of UK emissions in 1990
Carbon dioxide	CO_2	Burning fossil fuels Forestry, land use change	78
Methane	CH_4	Coal, oil, gas production Landfill, organic waste Animals	12
Nitrous oxides	N_2O	Chemical industry Catalytic converters Animal wastes Fertilisers	8
Hydrofluorocarbons	HFCs	Refrigeration Air conditioning	2
Perfluorocarbons	PFCs	Aluminium industry	0.1
Sulphur hexafluoride	SF_6	Electrical switching gear Magnesium industry	0.1

Source: DETR (1998)

Table 1.3: UK greenhouse gas emissions and their likely changes by 2010 as a result of currently planned policies and actions

Million tonnes carbon equivalent	1990	2000	2010	% change 1990-2010
Energy Sector †	72	55	59	-18
Business	87	70	75	-14
Transport	39	41	42	+8
Public Sector	10	9	9	-10
Agriculture, forestry and land use	26	23	22	-15
TOTAL	**216**	**189**	**194**	**-10**
Of which CO_2	168	157	163	-3

† Some energy sector emissions are also allocated to energy using sectors, so the figures in the columns do not add to the total

1.10 Measures on how best to use new economic instruments to improve the industrial and commercial use of energy and reduce emissions of greenhouse gases were considered in Lord Marshall's 1998 report, ‘Economic instruments and the business use of energy’. While there was consensus on the need for economic instruments, there was little agreement on how best to implement them. The main conclusions were that a mixed approach of the economic instruments of tradable emissions permits and/or taxes, coupled to existing regulations and

voluntary and negotiated agreements, was the appropriate way forward. Similarly, the Advisory Committee on Business and the Environment eighth progress report agreed on the need for a long-term partnership between government and business, and the need for business to be more involved in stimulating innovation, new technology, and harnessing the future commercial opportunities. The Chancellor's recent announcement of a climate change levy on energy consumption, to be introduced in 2001, is the most far-reaching climate change policy to date. The Chancellor also announced in March 1999 that a test-run of greenhouse gas emissions trading would be encouraged.

Climate Change Adaptation

1.11 Compared to work on climate change impacts and mitigation of greenhouse gas emissions, relatively little research has been conducted on the issue of integrated adaptation to climate change. There is a growing awareness of the need for such research given:

- The recognition that the climate is noticeably changing at the global level and, in the case of the UK, also at national and regional levels
- The recognition that climate change is likely to accelerate in the future, even if major greenhouse gas emission reductions take place in the next few decades, because of time-lags in the global climate system
- The uncertainty in climate change projections. It seems prudent therefore to consider policy development for a range of potential climate futures

1.12 There are two types of potential response to climate change. 'Autonomous' change relies on natural or social systems responding to changing conditions and is frequently incremental and unplanned. For example, changing patterns in the migration of birds or in the pattern of human social activities, such as increasing outdoor activities. 'Adaptation' relies on a deliberate response to identified changes resulting from the effects of climate change. Examples include the revision of building codes to reflect new patterns of climate and fitting of air conditioning systems to maintain comfortable working environments.

1.13 Adaptation involves the development of strategies to adapt to the impacts of climate change. These strategies will seek either to minimise potentially adverse effects, within the limits of scientific certainty, or allow the potential opportunities arising from climate change to be realised. A third function of climate adaptation strategies is to take a long-term overview of a sector, firm or organisation's activity. Climate change can provide an 'anchor' in a very uncertain future that can assist in 'futures visioning' on the part of policy makers, managers and other stakeholders. Hence, adapting to climate change can help in re-thinking organisational goals and values, and in re-organising and re-engineering the provision of goods and services to customers and users. One example of this is the way climate change has forced the question of what is the 'end point' of a biodiversity policy, given that a static view of nature conservation is not viable.

Scottish Developments on Climate Change

1.14 In 1998 the Scottish Office organised and reported on two workshops addressing the Scottish implications of climate change. The first considered the possible direct impacts of climate change on Scotland and the necessary information required for decision-makers to plan appropriate responses. The conclusions of this 'Climate Change Impacts in Scotland'

workshop were:

- There is a clear need for higher resolution climate data on Scotland
- Participants identified particular areas of potential concern for climate change impacts in Scotland:
    i. Salmon, marine and freshwater fisheries
    ii. Oil and gas infrastructure
    iii. Hydroelectric plant
    iv. Roads, coastal defences and other public infrastructure
    v. Water resources
    vi. Highland and subarctic ecosystems
    vii. Agriculture and forestry
    viii. Skiing industry
    ix. Health
    x. Environmental indicators to determine 'critical' levels of damage
- There are important public information issues that need to be addressed in Scotland
- There should be a new forum to advise Ministers and the Scottish Parliament on climate change

1.15 The second, held in November 1998, addressed the actions that might be needed to mitigate greenhouse gas emissions in Scotland. The 'Climate Change Mitigation Strategy for Scotland' workshop aimed to raise awareness about the key issues and challenges involved in developing a Scottish climate strategy, and to gather views from a range of sources concerning feasible and desirable measures to reduce greenhouse gas emissions (see box).

Issues identified by the UK Climate Change Programme consultation paper and discussed at the Scottish Office climate mitigation workshop

Transport

- increasing fuel duties
- voluntary agreements on car efficiency (EU agreement)
- alternative fuels, fuel cells, electric/hybrid vehicles
- best practice techniques for fleet operators
- demand management and model shifts
- user charges/traffic management

Households

- energy efficiency in the home – lights, appliances, central heating, insulation, advice and information
- financial incentives
- local authorities under Home Energy Conservation Act
- electricity Standards of Performance
- market transformation strategy (appliance suppliers/government)

Business

- fiscal measures to raise investment funds and provide incentives
- regulation (integrated pollution control)
- negotiated/voluntary agreements
- emissions trading
- targeted advice/assistance for SMEs

Energy supply

- investment in renewable energy and other non-fossil generation
- combined heat and power
- energy services for customers
- 'green' tariffs
- utility regulation

Land use and forestry

- expansion of woodland areas
- energy crops (biomass)
- animal husbandry
- reduced fertiliser use

1.16 In response to the conclusions of the workshops, the Scottish Office let a research contract to scope the Scottish implications of climate change. This report is the result of that research contract, and involves work carried out between December 1998 and July 1999. It is

one of the first to be conducted using the UKCIP climate scenarios and the first regional study to consider both climate impacts and means of mitigating greenhouse gas emissions.

PROJECT METHODS

1.17 This report represents a synthesis of information from different socio-economic sectors in Scotland concerning the future interaction between climate, the physical environment and society. Three sources of uncertainty lie at the heart of this interaction:

- future climate
- future socio-economic change, which determines the context of future climate change impacts and the means of adapting to climate
- translating future climate and socio-economic change into specific impacts on society and the environment

The approach adopted in this project to obtain the appropriate information about each of these uncertainties was to use the 'expert judgement' of a group of people from the private and public sectors (Table 1.4, Annex 1), in combination with the extensive recent literature relating to climate change in the UK. Expert judgement is a powerful technique for rapidly assessing the knowledge base and communicating the primary issues, risks and opportunities arising from a complex subject such as climate change.

1.18 A framework of critical issues for climate change was developed to guide discussions and identify important climate-related issues with the experts (see box below). For example, it is apparent that the economy, society and the environment will continue to evolve during the next century, whether there is climate change or not. It is important to try and distinguish in advance future change arising from the influence of climate from future change arising from numerous other social and economic pressures. The framework provided the means of assessing the quality and scope of climate change issues within Scotland. The information provided to experts is set out in Annex 2.

Information derived from experts and the literature seeks to:

- identify the factors that drive change in each sector in Scotland, and determine the relative importance of climate change to these factors
- consider the potential sensitivity of each sector to a change in climate
- assess the vulnerability of each sector to the range of possible future climates identified in the UK Climate Impacts Programme
- summarise the possible benefits of such climate change
- discuss the capacity and time-scale for each sector to adapt to climate change
- review the sensitivity of sectors to strategies for reducing greenhouse gas emissions
- provide a comparative assessment of the role of climate change on the different sectors and in different regions of Scotland

Table 1.4: Organisations whose staff have given expert opinion to this study

Aberdeen Coast Guard	Aberdeen Harbour Authority
Aberdeen University	Argyll & Bute Council
Amerada Hess	Association for the Conservation of Energy
Association of District Salmon Fishery Boards	Astra Zeneca
Automobile Association Scotland	Babcock Rosyth
Baxters of Speyside	Boots the Chemist
BP Chemicals and Oil, Grangemouth	BRE Scottish Laboratory
British Energy	British Energy Efficiency Federation
Caledonian McBrayne	Caledonian Paper
CBI Scotland	Coast Guard
Diageo	Digital / Compaq
Dundee University	Dunstaffnage Marine Laboratory
East of Scotland Water Authority	Energy Savings Trust
First Group	Fish Conservation Centre
Fisheries Research Services	Forestry Commission Scotland
Forth Ports	Friends of the Earth Scotland
Glasgow City Council	GlaxoWellcome
Grangemouth Harbour Master	Highlands & Islands Enterprise
Institute of Freshwater Ecology, Edinburgh	Institute of Freshwater Ecology, Windermere
Institute of Hydrology, Wallingford	Institute of Terrestrial Ecology, Edinburgh
Macaulay Land Use Research Institute	National House Builders Council
NEC Semiconductors	North of Scotland Water Authority
Rail Track Scotland	Royal Botanic Gardens
Royal Society for the Protection of Birds	Scottish & Newcastle
Scottish & Southern Electric	Scottish Airports Ltd
Scottish Borders Council	Scottish Centre for Infection and Environmental Health
Scottish Enterprise	Scottish Environmental Industry Association
Scottish Fishermens Federation	Scottish Homes
Scottish Landowners Federation	Scottish Natural Heritage
Scottish Office	Scottish Power
Scottish Renewables	Scottish Salmon Growers Association
Scottish Tourist Board	Shell Exploration
SmithKline Beecham	Tesco
Tullie Russel Paper Manufacturers	UK Offshore Operators Association
University of Durham	University of East Anglia
University of Edinburgh	University of Strathclyde
Walkers Shortbread	West of Scotland Water Authority

1.19 Information from the experts and the literature has been categorised into six sectors: energy; transport; business; domestic; agriculture, forestry and fisheries; and public services. They encompass social and economic spheres potentially affected by climate in Scotland and are broadly comparable to those characterised in the 1998 UK Climate Change Programme: Consultation Paper. The emphasis in each sector has been to detect its vulnerability to climate change impacts and climate change mitigation strategies, combined with a judgement on the confidence of prediction. This provides a comparative analysis of the sensitivity of different sectors to climate change. As such, it is the most appropriate approach for assessing and prioritising response strategies between the different sectors.

1.20 Public perceptions of the impact of climate change issues are not well known. In 1990, the (then) Scottish Office commissioned a major survey of public attitudes towards environmental issues in Scotland, some of which are related to climate change. The two most

important issues, according to the public, were pollution of rivers, lochs and seas and dumping of raw sewage at sea. Other issues of concern were the quality of drinking water, nuclear waste and damage to the ozone layer, followed by road traffic and fumes and smoke from factories. Information from expert respondents contributing to this report suggested a very varied attitude to climate change, a factor that requires consideration when deciding priorities for future work.

REPORT STRUCTURE

1.21 Chapter One provides a statement of the aims of the report, a review of the developments in climate change impacts, climate change mitigation strategies and climate adaptation strategies, and a brief overview of the approach used to obtain the information set out in this report.

1.22 Chapter Two details the climate scenarios of the UK Climate Impacts Programme, which represent the most comprehensive exploration to date of regional climate change in the UK. This comprises an analysis of the climate change scenarios for Scotland and a brief assessment of the strengths and weaknesses of such work. We also note other climate change research work in Scotland.

1.23 Chapter Three considers the implications of the impact of climate change on the natural environment of Scotland. This encompasses climate impacts on air, water and soil, and the implications for ecosystems and Scottish biodiversity.

1.24 Chapter Four contains the bulk of the research findings, which consider the impacts of future climate change in each of the different sectors and their possible response. The appraisal of each sector identifies the importance of climate change relative to the main drivers of change in the sector. The potential sensitivity of each sector to climate change is addressed before focusing on potential benefits or vulnerabilities with respect to the existing climate scenarios. This distinction between the potential sensitivity of a sector to climate change and its specific vulnerability to the existing UKCIP climate scenarios is important. As our capacity to predict climate change improves, new climate scenarios will be developed. However, the underlying sensitivity of a sector to climate change is unlikely to change markedly. Finally, the chapter considers the capacity of each sector to adapt appropriately to climate change.

1.25 Chapter Five presents the key topics concerned with reducing greenhouse gas emissions from different sectors in Scotland, in line with the Kyoto and Buenos Aires agreements and the UK Government's domestic targets. The chapter seeks to outline the policy options, rather than explore them in any depth, to provide a comparative assessment of the relative importance of climate impacts and climate change mitigation strategies.

1.26 Chapter Six presents the full comparative assessment of climate change issues in Scotland, and recommendations for future work. The devolved Scottish Parliament, consumer pressure and broader popular public opinion all have the potential to change the response of different sectors to climate change issues. This integrated assessment provides an overview of the strengths and weaknesses of our present understanding of climate change issues in Scotland.

CHAPTER TWO FUTURE SCOTTISH CLIMATE

Summary

The UK Climate Impacts Programme climate scenarios suggest that Scotland will become warmer, with relatively more warming in winter than summer. Rainfall is likely to increase, with autumn and winter seeing the biggest increases while spring amounts will drop and summer rainfall will remain similar to today. The intensity of rainfall events is likely to increase, leading to increased risk of flooding. The scenarios suggest a decrease in the number of gales overall, though there may be an increase in the frequency of very severe gales. The water balance is likely to remain favourable, which is important for the water industry and agriculture, while direct short-wave solar radiation is likely to reduce over the next century with increased cloud cover. Natural variability o the climate system is likely to modify the magnitude and patterns of these human-induced changes. Two possible 'climate surprises' are the collapse of the ocean circulation in the North Atlantic, which would have with dramatic consequences for European climate, and the collapse of the West Antarctic ice sheet, which would increase the rate and magnitude of sea level rise. Neither is thought likely to occur in the near future.

INTRODUCTION

2.1 In 1992, the Intergovernmental Panel on Climate Change (IPCC) published six scenarios of possible future global socio-economic change, termed IS92a-f. These 'futures', which assumed no further climate policies by Governments, provided climate scientists with the best available assumptions regarding future emissions of greenhouse gases by society. With this information on how humans might influence climate, scientists were able to explore future climate change scenarios. Scenario IS92a, which represented the middle of this range of socio-economic scenarios, was explored in some detail during the IPCC Second Assessment of 1995. One of the key conclusions of this work was that climate models were not sufficiently good to resolve confidently climate change on a national or regional scale.

2.2 Two reasons have been identified for the difficulty in predicting future climate. First, climate varies naturally over a range of time-scales and space-scales. Thecomplexity of the global climate system is only now being unravelled and uncertainties remain. Second, human society is altering the composition of the atmosphere. The climatic consequences of the industrial era are beginning to emerge with evidence of the human influence on global climate. The Hadley Centre of the UK Meteorological Office is one of the leading climate research centres and has contributed much to our understanding that human-induced change is likely to become increasingly important in the coming century. As a result of both natural variability and human-induced change, there is no longer confidence that climate statistics from the past will provide an adequate description of the future; hence modelling of future climate is required.

2.3 To enable future climate impact assessments to be undertaken in the UK, the UK Climate Impacts Programme (UKCIP) have produced a set of national-level climate change

scenarios, based on the best understanding of climate change in 1998. This chapter on the future Scottish climate draws heavily on this work of the UKCIP98 climate scenarios, which were based on a series of climate modelling experiments performed by the Hadley Centre using their HADCM2 model between 1995-1997. This model continues to be developed to enable improved climate scenarios to be produced in future. Similarly, for their Third Assessment the IPCC have produced four new scenarios or 'story-lines' of global socio-economic change, termed IS99. These scenarios will provide a new set of assumptions for climate modellers over the next few years. These scenarios represent annual global atmospheric carbon dioxide-equivalent concentration increases of 0.4, 0.7, 0.8, and 1.2 % respectively. These are generally lower than the one per cent annual concentration increase represented by the IS92a scenario, which reflects changing assumptions about global socio-economic development.

UKCIP CLIMATE SCENARIOS

2.4 Since no single climate change scenario can adequately capture the range of possible climate futures, the UK Climate Impacts Programme describes four possible climate futures for the UK, termed the UKCIP98 climate scenarios. These encompass a reasonable range of future climates and have been developed as descriptions of possible developments. At present, probabilities cannot be attached to the likelihood of any one of the scenarios. This range of climate futures reflects different assumptions about:

- The direction of future socio-economic change and hence the amount of global greenhouse gas emissions
- The sensitivity of the global climate to a change in greenhouse gas concentrations

2.5 The four scenarios are labelled **Low**, **Medium-low**, **Medium-high** and **High** which reflect their respective rates of global warming. The **Medium-high** and **Medium-low** scenarios encompass a range of future greenhouse gas emissions from society. The **Medium-high** scenario is based on an annual increase in carbon-dioxide concentration of 1 %, while the **Medium-low** scenario is forced with a per annum increase in carbon-dioxide concentration of 0.5 %. These are similar to the greenhouse gas emissions scenarios set out in the IPCC IS92a and IS92d socio-economic scenarios and exhibit future climates in the mid-range of possible global climate change. The **High** and **Low** scenarios aim to span the different climate sensitivities exhibited by different climate models. These scenarios are derived from the **Medium-high** and **Medium-low** scenarios respectively, by scaling their outputs to reflect an appropriate range of climate sensitivities.

2.6 The results of the climate scenarios are provided on a model grid, with cells representing an area with sides of approximately 300-400 km. As a result of this coarse scale, the model resolves only four discrete regions within the UK, two of which overlie Scotland. The first (the 'Scotland' grid cell) stretches over most of northern and central Scotland, but does not include areas of the West Coast, Orkney, Shetland and the Hebrides. The second grid cell (the 'Scotland/England borders') overlying Scotland covers part of the central belt including the Firth of Clyde Islands, the borders, plus northern England (see Figures 7 and 8, UKCIP, 1998).

2.7 There are two implications from the coarse scale of the model grid. First it produces a gross simplification of the actual coastline and landscape. For example, the central 'Scotland'

grid cell is defined to have an elevation of 221m. Such simplifications may modify the modelled climate change in comparison with the actual change. Second, none of the heterogeneity in land cover, which interacts with the atmosphere, can be captured in the model. As a result of these simplifications, the model cannot represent differences in climate change within a single grid cell. For example, it may rain more in west Scotland than in east Scotland in future, but the model cannot determine this result. In order to provide information of relevance for a Scottish climate impact assessment, this model information needs to be 'downscaled' to a scale appropriate for users.

Downscaling

2.8 'Downscaling' means adding spatial detail to the outputs of the coarse scale global circulation models. The UKCIP combine high-resolution climate records, using the 10 km UK climate dataset, with the outputs of the global circulation model. This approach, termed 'unintelligent downscaling', assumes that the climate change will be uniform over the area represented by the GCM grid cell and thus the basic spatial pattern of the present climate remains unchanged in future.

2.9 Other downscaling approaches are possible including statistical methods, which tend to be used for site or application-specific studies, or dynamic methods, which use higher resolution climate models embedded in the outputs of a GCM. This latter higher resolution technique provides more spatial detail of climate change, but is not necessarily more 'accurate', since the model output is entirely dependent on the quality of the input data produced by the GCM. Nevertheless, this and associated approaches hold much promise for future work and have been adopted by various modelling centres, including the Hadley Centre.

Uncertainties in the scenarios

2.10 Uncertainties are inherent in the development of climate scenarios, though this does not necessarily imply a lack of knowledge. There is more confidence in the prediction of some elements of the future climate than others. The UKCIP report provides a judgement of the relative confidence of the accuracy of different climate variables in the scenarios. They are shown in the box below:

Climate attribute	**Level of confidence**
Atmospheric CO_2	High confidence
Global mean sea level	↓
Global mean temperature	
Regional seasonal temperature	
Regional temperature extremes	
Regional seasonal precipitation	
Regional cloud cover	
Changes in climatic variability e.g. daily precipitation regimes	Low confidence
Climate surprises (e.g. shifts in ocean currents or ice sheet collapse)	Very low or unknown

CLIMATE CHANGE IN SCOTLAND

Temperatures

2.11 Scotland has a cool maritime climate. Temperature decreases with distance northwards and with altitude, while the influence of the Atlantic Ocean modifies this north-south pattern by moderating extremes of temperature, causing milder winters and cooler summers in the west and on offshore islands compared with the east. There is a great variability in the weather because of the interplay between polar, continental and tropical maritime air masses over the country. In combination with the maritime influence and the range of altitudes within Scotland, this results in a wide range of climatic conditions. The climate scenarios are unable to represent these temperature variations within the Scotland grid cells. The average winter temperature (December/January/February) in the 'Scotland' grid cell in the period 1961-90 was 2.2°C, and in the 'Scotland/England borders' grid cell for the same period was 3.0°C. Similarly, the average summer temperature (June/July/August) in the Scotland grid cell was 11.9°C in the period 1961-90 and13.3°C for the southern cell for the same period.

2.12 All four scenarios suggest warming will occur in Scotland by between approximately 0.1 to 0.3°C per decade, which is similar to the predicted global average. The scenarios suggest the average annual temperature rises, from the 1961-90 average, shown in Table 2.1. Figure 2.1 shows graphically the range of possible temperature changes described by the two extreme end-members of the four UKCIP scenarios, the **High** and **Low** scenarios.

Table 2.1: The temperature rise in degrees Centigrade from the 1961-90 average in the 'Scotland' grid cell under different climate scenarios

Scenario	2010-2039	2040-2069	2070-2099
Low	+0.4	+0.7	+0.9
Medium-low	+0.8	+1.2	+1.5
Medium-high	+1.1	+1.6	+2.3
High	+1.2	+1.9	+2.6

Source: Hulme and Jenkins (1998)

2.13 The figures for the 'Scotland/England borders' grid cell are fractionally higher. Seasonally, there will generally be more warming in winter than in summer. The future change in Scotland's temperature is less than that of the remainder of the UK, reflecting the stronger influence of the adjacent Atlantic Ocean in moderating extremes of temperature. Daily temperature ranges will be modified by between +0.1 and -0.5°C, with the largest reductions in the spring and summer and small increases during the autumn.

2.14 Changes in the year to year variation of temperatures are also important in determining climate impacts and will change through time. The UKCIP report provides one analysis for the **Medium-high** scenario, which shows winter temperatures becoming progressively less variable, while spring and summers show a less marked trend but may become more variable. In combination, these changes suggest fewer days with a minimum temperature below freezing. The UKCIP **Medium-high** scenario suggests a drop in the annual accumulated degree-days with a minimum temperature below freezing of up to 80% by the 2080s. The number of degree-days with an average temperature above +5.5°C, which is indicative of the plant-growing season, increases by between 3 and 7% per decade.

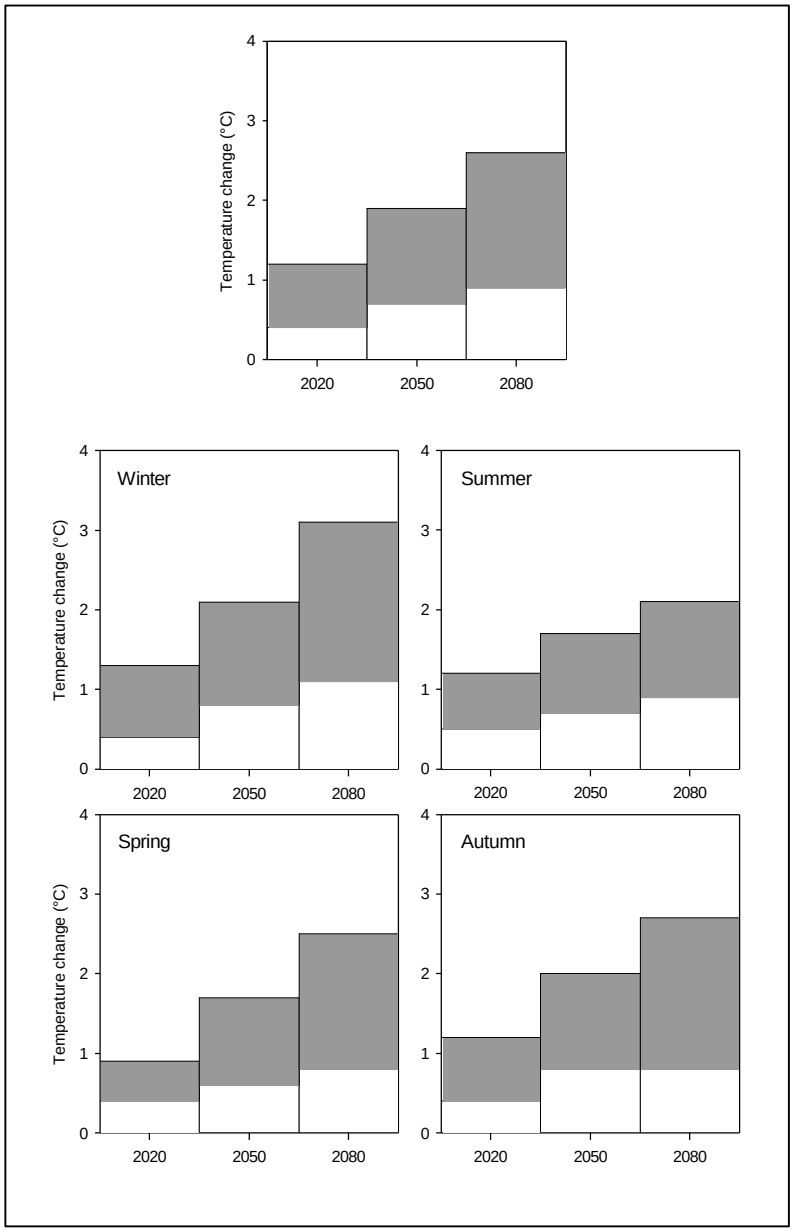


Figure 2.1: The future range of temperature change predicted by the four UKCIP scenarios for the 'Scotland' grid cell

Similarly, the number of degree-days with a maximum temperature above 25°C, which is indicative of the requirement for air-conditioning, more than trebles by the 2080s.

Precipitation

2.15 Scotland has a strong west-east precipitation gradient because of the prevailing moist westerly winds. Precipitation totals can exceed 2.5 m per year in the west and include a high number of wet days, while sheltered eastern areas may receive less than 1 m per year and have relatively few wet days. This general precipitation gradient is strongly modified locally by the mountainous landscape of Scotland. The existing trend is for increasingly wet weather in the west and dryer weather in the east. These precipitation patterns cannot be represented in the climate scenarios, which use a single average precipitation total for the 'Scotland' and

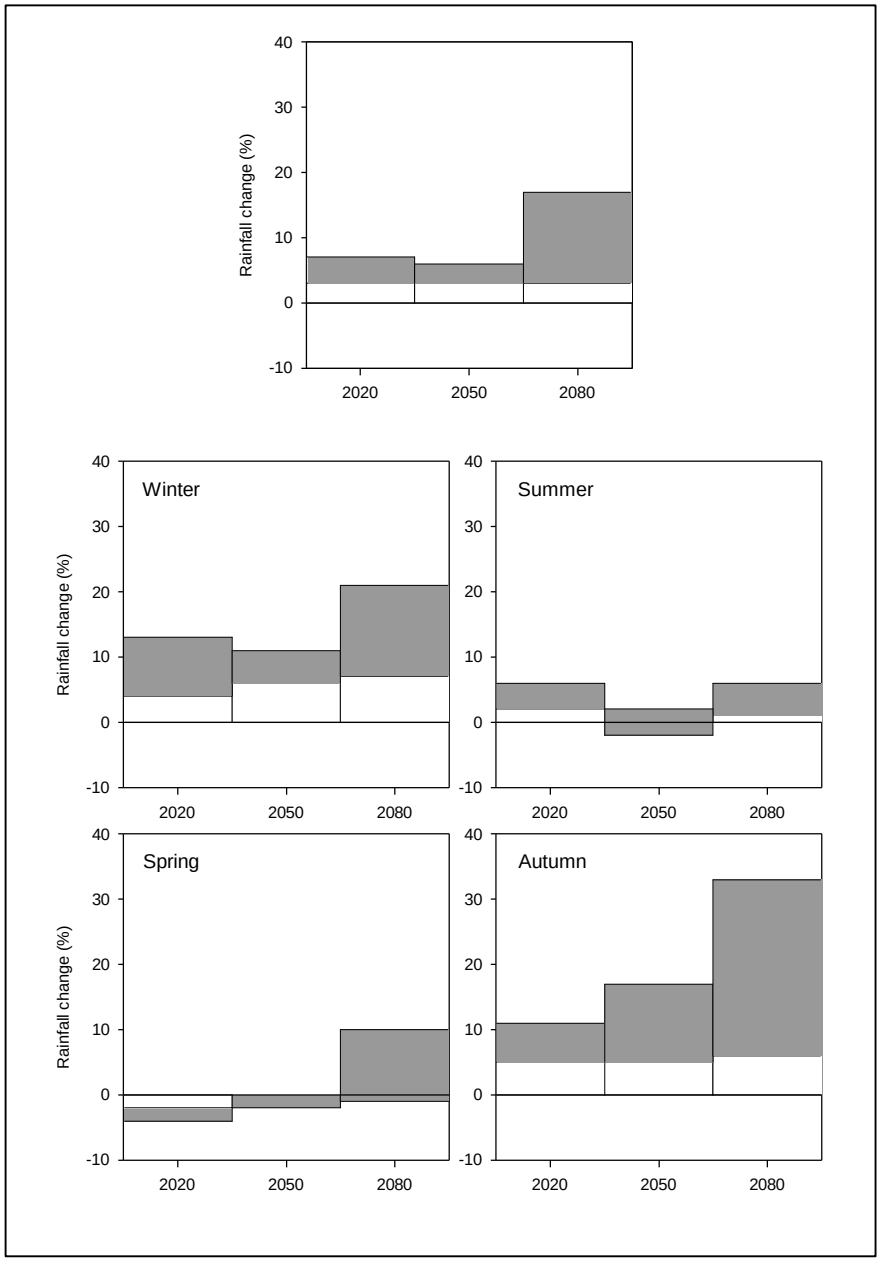


Figure 2.2: The future range of precipitation change predicted by the four UKCIP scenarios for the 'Scotland' grid cell

'Scotland/England borders' cells. The average annual precipitation over the 'Scotland' grid cell in the period 1961-90 was 427 mm in winter (December/January/February) and 289 mm in summer (June/July/August).

2.16 The climate scenarios suggest that the average precipitation totals in the 'Scotland' cell are likely to increase (see Table 2.2 and Figure 2.2, showing the seasonal variation in the range of precipitation predicted under the four scenarios). Similar figures are predicted in the 'Scotland/England borders' grid cell. Seasonally, the biggest increases are in autumn, with lesser increases in winter, while there will be a little less rainfall in spring and similar amounts in summer. The analysis of the **Medium-high** scenario suggests that year to year variation in precipitation will increase in every season but with marked changes between seasons and time-periods. These changes in the overall amount of precipitation will be accompanied by changes in the number and intensity of precipitation events. In the northern UK, precipitation intensities in the **Medium-high** scenario increase in both winter and

summer, with the most intense events becoming perhaps several times more likely than at present. This is likely to lead to greater risk of flooding.

Table 2.2: The precipitation rise from the 1961-90 average in the 'Scotland' grid cell under different climate scenarios

Scenario	2010-2039	2040-2069	2070-2099
Low	+3%	+3%	+3%
Medium-low	+4%	+5%	+6%
Medium-high	+6%	+5%	+16%
High	+7%	+6%	+17%

Source: Hulme and Jenkins (1998)

2.17 Precipitation over Scotland's mountainous landscape falls as snow over much of the winter and spring, and snow can lie in a few isolated sites for much of the year. Snowfall increases with altitude while snow lie depends on a subtle combination of factors such as aspect, prevailing wind direction and temperature. Evidence from this century shows wide fluctuations from place to place and year to year. The climate scenarios cannot provide a direct assessment of future changes in snowfall and snow lie, though it is important for the winter leisure industry. Further work is required.

Wind speed

2.18 Wind speed in Scotland varies depending on the season, the elevation and the aspect High wind speeds are recorded in the west and in the uplands, where gusts of 66 m/s (~235 km/hr) have been recorded in the Cairngorms. High winds are most often associated with westerly fronts. The average number of days with gales decreases from over 30 in the north-west to 2-5 days per year in sheltered eastern areas. Weather records suggest that storms have increased in severity and frequency in recent years.

2.19 In the future, annual mean wind speeds are likely to increase a little relative to the 1961-90 average. Seasonally, an increase in autumn, a small reduction in spring and little change in winter are predicted. Summer mean wind speed may increase slightly by the 2080s. Perhaps a more useful statistic is the change in daily mean wind speeds, associated with storms. The UKCIP analysis suggests that there will be more frequent days in summer with high summer wind speeds, but little change in winter daily extremes. The UKCIP report also provides an analysis derived from the **Medium-high** scenario of changes in gale frequency over the entire UK. The report differentiates normal, severe and very severe gales. Overall, winter gale frequencies decrease although the average frequency of very severe winter gales increases in the 2020s and 2080s periods but decreases in the 2050s. All types of summer gales, of which there are relatively few, increase in average frequency in the 2020s and 2080s but decrease in the 2050s. The figures suggest that it is difficult to distinguish human-induced changes in gale frequency from the extensive natural climate variability.

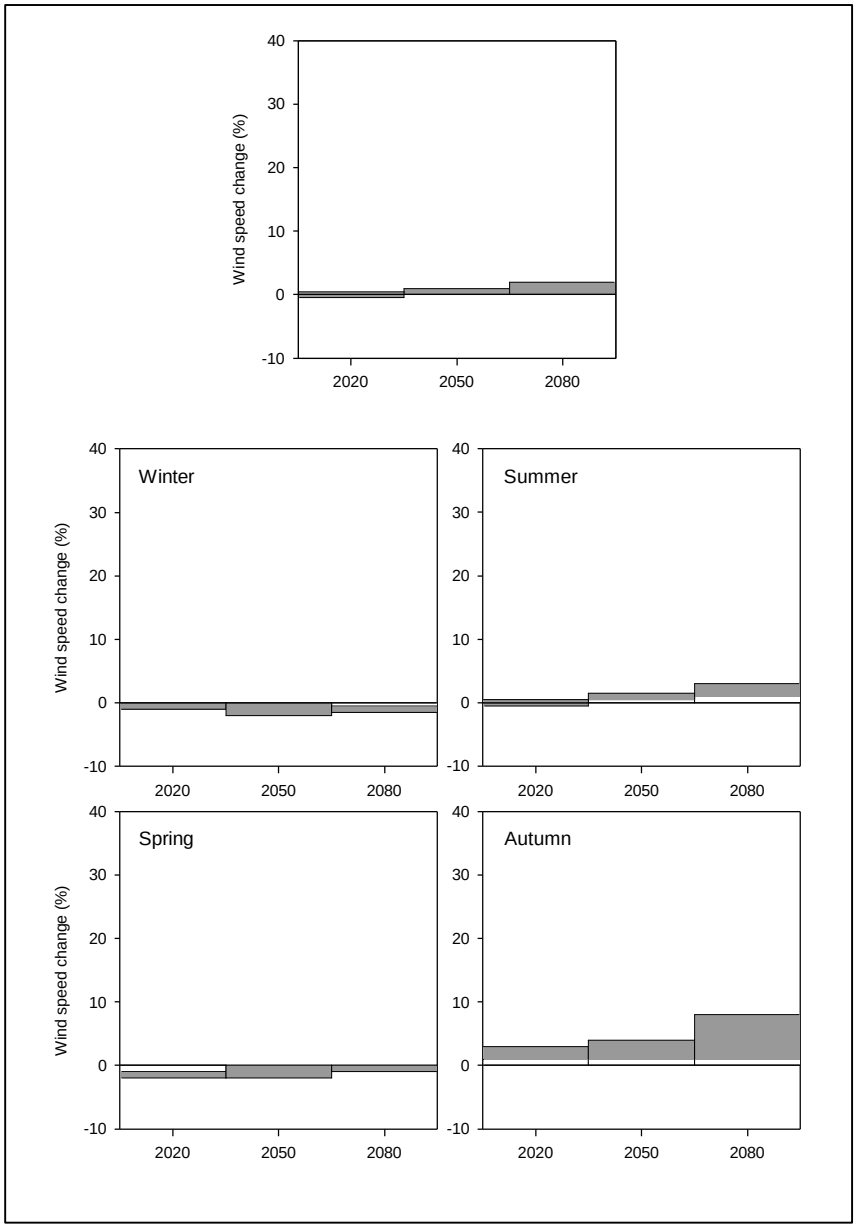


Figure 2.3: The future range of mean wind speed change predicted by the four UKCIP scenarios for the 'Scotland' grid cell

Other variables

2.20 The UKCIP report details a range of results for additional climate variables under the **Medium-high** climate scenario. Here, we consider briefly results for short-wave radiation and cloud cover, since these have health implications, and potential evaporation, since this is an important environmental measure of the 'drying' strength of the atmosphere.

2.21 The predictions suggest that annual cloud cover is unlikely to change much in Scotland over the next century. Seasonally, cloud cover increases slightly in winter but decreases in autumn despite the increased precipitation. Spring and summer see increases in cloud cover by the 2080s. Short-wave radiation is closely related to cloud cover; as cloud

cover increases, short-wave radiation decreases. As a result, short-wave radiation is likely to decrease in every season and every time-period apart from autumn, when cloud cover decreases.

2.22 Potential evaporation is predicted to remain stable in winter. Little change in summer is also predicted, which together with the expected small increases in rainfall suggest that the water balance will remain favourable in Scotland. The results indicate a slight increase in potential evaporation in spring and a substantially greater increase (up to 16%) in autumn, reflecting the higher wind speeds, lower cloud cover and higher incident short-wave radiation.

Natural variability

2.23 Natural variability in the climate will modify the magnitude and patterns of change described above. The natural variability of the UK climate is large, especially for climate variables such as precipitation and wind speed, and will itself be modified as a result of future climate change. This makes it more difficult to attach high levels of certainty to whether the changes presented here result from natural or human-induced change. The UKCIP presents estimates for the uncertainty arising from natural variability by the use of ensembles of identical experiments with the climate model. A series of ensemble experiments, using precisely the same historical and future changes in greenhouse gases, are initiated from different points in time of the control climate experiment, which is the baseline experiment run for hundreds of simulated years to ensure a modelled climate unperturbed by any external influences. The difference in results between the experiments provides a measure of the extent to which future changes are human-induced or result from natural variations. The conclusion of the UKCIP report is that such measures should always be used in preference to single experiments for climate impact assessment. For example, changes in predicted temperatures vary by ± 20% between individual ensemble experiments. Since temperature change in the scenarios is much larger than this, there is confidence that the change is human-induced. Conversely, predicted precipitation change, particularly for the 2020s, is similar to the variation in change found between individual ensemble experiments. This suggests that a large proportion of the seasonal precipitation change, in the **Medium-high** scenario for which the analysis has been done, is probably due to natural variability rather than human-induced change.

Climate surprises

2.24 While the four scenarios provide an internally consistent set of possible UK climates in the future, other events about which there is less knowledge are possible. One is the collapse of the West Antarctic ice sheet, which would increase the amount and rate of sea level rise. Numerous studies of the sensitivity of the West Antarctic ice sheet are ongoing, including work by the British Antarctic Survey, but there is little consensus on a quantitative estimate of the probability of collapse. The DETR are funding a formal risk assessment of this event, which will be completed later this year. A second and more profound possibility concerns changes to the ocean circulation in the northern North Atlantic. Ocean currents transport large amounts of heat around the world. It is thought that under certain conditions the present ocean circulation in the North Atlantic could collapse, leading to cooler conditions over north-west Europe. The last time this is believed to have occurred was about 11,000 years ago, during the Younger Dryas era, when glaciers grew in west Scotland. Model evidence suggests that the formation of dense water at high latitudes, which drives the

present ocean circulation, will be suppressed by global warming through increased input of fresh water into the North Atlantic and reduced ocean surface heat loss. Under such conditions, it has been suggested that the present ocean circulation will become more prone to collapse. Though thought unlikely to occur in the near future, any changes in this circulation would have a profound impact on life in north-west Europe. Studies funded by a variety of international and national agencies, including the UK Natural Environment Research Programme through its ARCICE research programme, are researching the mechanics of these ocean currents. No formal risk assessment has been undertaken.

SCOTTISH CLIMATE RESEARCH

2.25 Complementing the work of the UKCIP, researchers in Scotland continue to improve our understanding of the Scottish climate. While there are reasonable terrestrial climate records with which to explore regional variation across the country, there are few records from the uplands and a scarcity from marine environments apart from the ocean temperature records obtained by the Marine Laboratory, Aberdeen. A research project, funded by the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER), is developing Scottish temperature indices to provide a baseline with which to evaluate trends that may be occurring in Scotland and its waters. Other research exploring the current trends of climate in Scotland includes studies of changes in precipitation and flood risk across the country and the implications of temperature changes for skiing and tourism (Harrison, 1997; Werrity, 1999).

GLOBAL IMPLICATIONS OF CLIMATE CHANGE

2.26 As well as the direct climate impacts on Scotland, Scotland will be affected by the impact of climate change on other countries. For example, some agricultural regions will be threatened by climate change while others may benefit. Heat stress, shifting monsoons and drier soils may reduce yields in the tropics and subtropics, while longer growing seasons may boost yields in northern Canada and Europe. Similarly, the regional pattern of water resources will change, adding further stress to existing issues of pollution, growing populations and economies, while climate change will affect the frequency, magnitude and location of extreme events, such as heat-waves. At present, projections of regional climate change and the resulting impacts are full of uncertainties.

CHAPTER THREE SCOTLAND'S NATURAL ENVIRONMENT

Summary

This chapter provides a brief review of Scotland's natural environment and the implications for the environment of the UKCIP climate scenarios. Climate is one of the main factors shaping the Scottish environment. The Scottish landscape reflects the history of glacier inundation in past millennia, producing the familiar topography of the mountains and glens, and the characteristic soils. More recently, human influences have interacted with climate, topography, soils, fauna and flora to produce the environment and ecosystems that many seek to protect today. Indeed, there are few areas in Scotland without visible signs of past or current human management. Extensive research, by Government agencies, research institutes and university departments has been done over the last few decades in Scotland to improve understanding of the processes affecting the natural environment. Much has been achieved, but the appreciation of climate change and its possible impacts is relatively recent, and sets new challenges for the research community. Similarly, there is already a large body of policy and legislation seeking to protect the environment in Scotland, but as new research findings improve understanding of climate change, it is likely that new or adapted measures will be needed.

3.1 Scotland's natural environment will be affected by both the direct impacts of climate change and by strategies to mitigate greenhouse gas emissions. Direct impacts will occur on the quality of the air, water and soils, and the life cycles of plants and animals, with resultant impacts on ecosystems. Indirect impacts will occur as a result of measures taken to reduce greenhouse gas emissions. Land use has a proportionately larger influence on Scottish greenhouse gas emissions than in the rest of the UK, because of the Scotland's large land area, relatively small population, and the importance of agriculture and forestry. Changes in land use, such as expansion of forestry (increasing uptake of carbon dioxide) or reduction in intensive agriculture (reducing nitrous oxide emissions), whether as a result of climate change mitigation policies or as a by-product of other socio-economic forces, will affect the net emissions of greenhouse gases from Scotland.

3.2 The following discussion of climate impacts on the natural environment is divided into sections dealing with air quality, soil, water and ecosystems and biodiversity. This provides a convenient framework to consider impacts, though there are linkages between these different areas and material dealt with elsewhere in this study, particularly with respect to agriculture, forestry and fisheries.

Air quality

3.3 Air quality is dependent on a number of natural and human factors, such as the prevailing weather and the emission of pollutants. Each pollutant is sensitive to emission, transport and deposition factors. Differences between the way pollutants behave in the environment mean the effect of releases into the atmosphere may be seen either close to the source of emissions or considerable distances away. Greenhouse gases, unlike for example

acid rain, have global effects resulting from their long life times in the atmosphere, allowing them to be distributed over very long distances by the global atmospheric circulation.

3.4 Different sources of emissions make differing contributions to levels of pollutants in the air. Of the six greenhouse gases (identified in Table 1.2), carbon dioxide results from energy use in the business and domestic sectors and fuel combustion in transport and the energy supply industry. Significant emissions of methane arise from the coal, oil and gas industries, business and domestic waste from landfill, and digestive processes in animals and their waste. Industrial processes and agricultural practices, particularly use of fertilisers, are primarily responsible for emissions of nitrous oxide. The remaining three greenhouse gases, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride, are primarily generated by industrial processes associated with the manufacture of refrigerants, aluminium production and the magnesium industry.

3.5 Emissions from human activity can be controlled by applying standards, such as vehicle emission and fuel standards, or by regulating emissions from industrial, commercial and domestic sources directly. At present, the Scottish Environment Protection Agency has the statutory responsibility for control of air pollution. The National Air Quality Strategy sets health based objectives for 8 major pollutants (benzene, 1,3-butadiene, carbon monoxide, lead, nitrogen dioxide, ozone, fine particles [PM10], and sulphur dioxide) to be met by, or before, 2005. At the core of the Strategy is a requirement for local authorities to undertake Local Air Quality Management (LAQM), and to declare an Air Quality Management Area (AQMA) if one or more of the objectives are unlikely to be met by 2005. The forthcoming introduction of the EC Directive on Integrated Pollution Prevention and Control (IPPC) is likely to have a significant impact in this area. Economic instruments are another means of controlling emissions, for example excise duties and the fuel escalator to reduce road traffic.

3.6 Climate change is likely to affect air quality by the direct impact of changes in precipitation and temperature and from the indirect impact of climate mitigation strategies, as a result for example of changes in land use. Changes in the gradients of temperature and rainfall from west to east and the prevailing winds will affect the risk of smog and low-level ozone formation.

Water

3.7 In general, water is plentiful in Scotland, though changes in precipitation across Scotland are now becoming apparent. Both long-term and short-term records show precipitation increasing in the north and west of Scotland, and decreasing in east and south. Similarly, significant increases have been observed in the spring, autumn and winter in the north and west, while there have been decreases in the east in summer. Summer flows of rivers have generally declined throughout Scotland, but not sufficiently to generate significant change. Higher winter rainfall and wetter catchment conditions are likely to result in higher frequency of floods in winter. There has been a series of major floods since 1989, but no consistent increase in the size of moderately high river flows. The effect of snowmelt on water resources in Scotland is not well understood and presents serious problems for flood forecasting. The Government position on flooding in relation to the built environment is set out in the National Planning Policy Guidelines 7. It comments that susceptibility of land to flooding is a material consideration in deciding a planning application. These land areas include flood plains and low-lying coastal areas within or adjacent to a watercourse.

3.8 Demand for water is likely to rise as a result of further house building and the irrigation requirements of horticulture and agriculture, particularly in areas such as East Lothian and Fife. This will result in increased abstraction of both surface and ground water. In conjunction with lower summer river flows, such changes in water resources affect the pollution control of surface waters. With lower river flows, there is less water to dilute pollutant discharges, so tighter consents will be required, resulting in higher treatment costs for sewage and industrial discharges. Conversely, high river flows will increase the dilution of pollutants, but may lead to a requirement for improvements in infrastructure, particularly for combined sewer outflows and storm tanks (increased capacity would be required), for compliance with European Community Directives. These issues are considered further in the Water Resources section of the Public Services sector in Chapter 4.

3.9 Higher water temperatures will accelerate natural biodegradation of organic pollutants, but increase the risk of algal blooms, especially in rivers and lakes affected by eutrophication. Algal blooms generally cause a decrease in the oxygen concentration of the water as oxygen is used up in the decay of dead algal material. In severe cases, this can reduce the oxygen below the concentration required for fish to survive. Lower summer river flows and higher temperatures may cause a general decrease in oxygen concentration that will tend to tip the competitive balance towards coarse fish, such as pike, and away from salmonid fishes, such as trout and salmon, which prefer highly oxygenated water.

3.10 The Scottish Environment Protection Agency has the statutory responsibility for control of water pollution in Scotland. Its recent report, 'Improving Scotland's Water Environment' (SEPA, 1999), shows that while much has been done to improve the quality of surface water in Scotland since the 1965 Rivers Act, much remains to be achieved. The primary drivers of change for water resources are human pressures from population, industry and land use change, coupled to changing precipitation patterns.

3.11 Coastal sea level is affected by both changes in the volume of water in the ocean, and changes in the altitude of the coast caused by movements of the Earth's crust. Climate warming will inevitable increase the volume of water in the ocean as a result of thermal expansion. Melting of glaciers or ice-sheets will provide a further increase. The likely changes in altitude of the land surface are relatively well known in Scotland. The land surface is rebounding, by a few millimetres a year, from the weight of glaciers, hundreds of metres thick, that inundated the landscape during the last ice age over 10,000 years ago. Uncertainty in future sea level rise around Scotland lies in the lack of knowledge about the size and rate of change in ocean volume resulting from the melting of glaciers and ice-sheets, such as those of Greenland and Antarctica. A project, funded by the Scottish Natural Heritage is presently examining the impact of climate change on sea levels around Scotland.

Soils

3.12 The Macaulay Land Use Research Institute (MLURI) holds a National Soil Inventory comprising descriptions of site characteristics and soil profiles across Scotland. Outwith the intensively managed agricultural area (which are considered in the Agriculture section of Chapter 4), Scotland's soils are generally rich in organic matter. This results from the lower rates of decay of plant litter (fallen leaves, twigs, branches) that occur in a cool and wet climate, nutrient poor and acidic. These soil characteristics are very important in determining

the type of vegetation, favouring communities such as heather moorland, rough grassland and pine forest.

3.13 Any increase in temperature will tend to increase the rate of decay of plant litter, speeding the release of nutrients into the soil (particularly nitrogen), which will increase plant growth rates. Atmospheric deposition of nitrogen, originating from human activities, is already increasing plant growth rates by enhancing soil nutrient status (particularly noted by forest researchers), and increased rainfall could produce higher deposition rates. The increase in atmospheric carbon dioxide concentration itself will tend to promote plant growth though its effect on photosynthesis. Many of the characteristic vegetation types (e.g. heather moorland, high altitude heaths) are adapted to nutrient poor conditions, and enhanced soil fertility and conditions for plant growth are likely to allow invasion by more competitive species, possibly resulting in the shifting of boundaries between vegetation types.

3.14 Soil erosion generally refers to the loss of the biologically active top soil, as a result of the removal of soil particles, caused by wind or surface run-off of water, especially on sloping ground. Increases in rainfall, and particularly rainfall intensity in association with storms, could potentially increase soil erosion. The expert respondents reported that soil erosion is not generally considered to be a problem in Scotland, and that the predicted climate changes were unlikely to increase soil erosion significantly.

3.15 Soils at high altitude are subject to repeated freeze-thaw cycles during winter, that cause movement of particles in the surface layers of the soil, a process known as solifluction. The predicted increase in temperature will tend to reduce the intensity of this process. This might be significant for low productivity plant communities that are adapted to tolerate solifluction, but would be unable to compete with more vigorous species that are currently excluded by the frequent disturbance of the soil.

3.16 Peatlands are an extensive and characteristic feature of the Scottish landscape. The peat is formed by the continual growth of mosses (*Sphagnum* species) favoured in poorly drained areas with a cool oceanic climate. The peat is formed from the accumulated remains of the living moss, that build up over hundreds of years, due to the slow decay rates of plant material in cool, water-logged soils, forming peat layers that may be many metres thick. These peat accumulations represent significant quantities of carbon, and changes in climate and land use could change the rates of its conversion to carbon dioxide or methane, both of which are greenhouse gases. Increases in temperature will tend to increase the rates of both processes, but the balance between them will depend on changes in rainfall. Increased rainfall favours anaerobic conditions (lower oxygen supply as more soil pores are filled with water), which enhances methane production, while lower rainfall dries the peat, favouring oxidation to carbon dioxide.

3.17 Afforestation of peatlands tends to dry the peat, increasing carbon dioxide production, tending to offset the uptake of carbon dioxide by the trees as they grow. This means that mitigation policies based on the afforestation of peatlands need to be assessed carefully to ensure that a favourable change in the net carbon balance actually results.

Ecosystems and biodiversity

3.18 Scottish Natural Heritage (SNH) has the responsibility of advising on policies for, and management of, the natural heritage and countryside of Scotland. SNH defines National

Scenic Areas, and designates Sites of Special Scientific Interest (SSSI). It identifies actions likely to damage designated areas and is empowered to enter into agreements with owners to safeguard the nature conservation of sites. Areas of national nature conservation significance are declared National Nature Reserves.

3.19 The SNH study, 'Changes in Scotland's Land Cover' (SNH, 1998), examined land cover change between the 1940s and the late 1980s. This period reflects an era of expansionary coniferous afforestation, agricultural intensification and urban development. Large areas of uplands were drained and converted to conifer plantation, with the loss of mire, heather moorland and rough grassland. Grassland improvement, arable expansion and agricultural specialisation were responsible for the main changes in the lowlands. Transport links were improved and urban development encroached on mainly lowland agricultural land. At present, over 50% of Scotland's vegetation is semi-natural, of which heather moorland (9%) and peatland (8%) are the most extensive single types. They also make up a further 22% of the total land as a mix of the two. Woodland cover is about 12%, which is broadly comparable with arable agriculture (11%) and grassland (13%).

3.20 The 'Land cover of Scotland' (MLURI, 1988) has been re-classified to show land cover groups comparable with the broad habitat types of the UK Biodiversity Action Plan. Scotland supports significant populations of species named in the EC Habitats and Species Directive including otter, freshwater pearl mussel and bottle nosed dolphin. Many scarce or threatened species are either endemic to Scotland or are restricted to Scotland within the UK.

3.21 SNH recently completed a major study of the impact of climate change on biodiversity in Scotland (SNH, 1999), which forms the basis of the rest of this section. Although the climate scenarios used in that report are not entirely comparable with the UKCIP climate scenarios, similar trends in environmental impacts would be expected.

3.22 The climate tolerances and other environmental requirements of species are largely fixed. Their response to change is through dispersal, death, invasion and displacement. Evolutionary responses are rare and exceptional, as these can only generally occur over much longer time periods. Small genetic adjustments, for example in timing of hatching, are possible for short-lived organisms such as insects and migratory birds.

3.23 Species behave individualistically. Communities are assembled from the species that are available and do not themselves, as a whole, disperse to new localities. Some organisms, including many birds, mosses and aphids, have very effective dispersal, allowing them to rapidly reach newly available habitat, others may take much longer. The difference in rates of dispersal, death and displacement suggest that new assemblies of species will be created by future climate change. The complexity of relationships between species therefore makes it difficult to predict some of the changes in biodiversity that will result from climate change.

3.24 The predicted rise in sea level is not large enough to have a significant impact on rocky coasts. On "soft" coasts, fringed by mudflats and saltmarshes, where there are no sea defences, the shoreline may move inland. Where there are no protective sea defences, the area of saltmarshes could shrink as they are inundated at their seaward edge, and restrained from expanding inland by the defensive barriers. The low lying firths of Scotland are most vulnerable to this potential loss of saltmarsh and mudflats, which support internationally significant numbers of overwintering ducks, geese and wading birds, and are important staging areas during annual migrations.

3.25 In alpine and subalpine habitats, a 1.8ºC rise in temperature will be roughly equivalent to a 300m decrease in altitude. This effectively raises the lower altitudinal limit for mountain species, reducing the total areal extents of their ranges in Scotland. Effects will include loss of persistent snow patches, reduced solifluction and invasion of more competitive plants and animals from lower altitudes.

3.26 The effects of climate change on mountain birds, notably ptarmigan, dotterel and snow bunting will undoubtedly be negative. The snow bunting depends directly on snow as a habitat and may become extinct in Scotland. Losses of high altitude subarctic willows, and other arctic-alpine plants currently restricted to north facing corries on mountains, are almost inevitable.

3.27 Despite these threats to some coastal and mountain species, the general impact of climate change is not drastic, and naturalists can be confident that many interesting organisms will persist. Indeed, many of the species on the UK Biodiversity Group's Priority List will either be little affected by climate change, or may respond positively to it.

3.28 The perception of climate impact on biodiversity in Scotland depends on whether a 'global' or 'local' outlook is taken. From a global perspective, since biodiversity is generally higher in warmer climates, climate change might be considered a small problem, as biodiversity will probably increase as species requiring higher temperatures migrate from further south. Also, some of the species that are rare here, being found at the extreme southern edges of their ranges, are relatively common in other countries. If the perspective taken is 'local', then there is a focus on the potential loss of characteristically 'Scottish' species, which results in a much more negative perception of the impact of climate change on biodiversity.

3.29 There are a number of possible management responses to possible climate induced changes in biodiversity. Habitats can be managed to maintain them in their current condition despite climate change, or natural succession (change) can be allowed to occur. Attempts can be made to control competitors, translocate threatened species to more suitable areas or create new habitats. More research will be needed to allow prioritisation of these management responses, and assess their feasibility and effectiveness.

3.30 A possible response to the potential loss of coastal mudflats and saltmarshes is that of "managed re-alignment", a term that describes the creation of new habitat by allowing inundation of low-lying coastal land, sometimes requiring the breaching of sea defences to allow inland movement of water. Experience in other parts of the UK suggests that inundated areas of coastal grassland are colonised rapidly by saltmarsh. In Scotland, where coastal landowners are responsible for the upkeep of sea defences, this may be a cheaper option than upgrading them to cope with rising sea level, as well as ensuring the continued availability of wildlife habitat.. Agri-environment payments are available to farmers to encourage the conversion of agricultural land to saltmarsh.

CHAPTER FOUR IMPACTS OF AND ADAPTATION TO CLIMATE CHANGE

4.1 This chapter details information about the impacts of, and means of adapting to, climate change in Scotland. The society, economy and natural resources of Scotland are divided into seven sectors: Energy; Transport; Domestic; Public Services; Business; and Agriculture, Forestry and Fishing. This division provides a convenient structure with which to explore the impacts of climate change and is broadly comparable to the sectors identified in the 1998 UK Climate Change Programme Consultation Paper.

4.2 For each sector, the aim is to set out the pivotal information that is required to respond appropriately to climate change. This information can be summarised as:

- the importance of climate change *relative to other factors* in forcing a response from the sector
- the sensitivity and vulnerability of the sector to climate change
- an assessment of the likely benefits of climate change
- the time-scale and likelihood of adaptation to climate and the extent to which this involves reaction to or anticipation of the change

ENERGY

Summary: Energy

Climate change is one uncertainty of many in a fast changing sector and not the most significant. The sector is dependent on many factors including on-going legislation. The primary vulnerabilities are associated with sea level rise, storm damage and intense precipitation events. Large-scale infrastructure will require a long lead-time to adapt to climate impacts. Customers will ultimately pay for the additional cost of climate impacts borne by industry.

4.3 For the purposes of this discussion, the energy sector is defined as that involved in the production of fuel and electricity for final consumption by other sectors. This includes electricity generation, oil production and refining, gas extraction and transmission, and extraction of coal and other solid fuels. Electricity; coal, oil and gas; and nuclear energy, are reserved matters for the UK Parliament under the Scotland Act. Any future regulatory framework for the energy sector cannot be considered solely at a Scottish level.

4.4 The aim of the discussion is to identify the issues relating directly to climate impacts in the energy sector. It does not seek to second-guess the market or the existing regulatory framework within Great Britain. Issues concerned with the future mix of generating capacity and the reduction in emissions of greenhouse gases are considered in Chapter 5.

State of the sector

4.5 The Government's prime objective for energy is to ensure a secure, diverse and sustainable supply at competitive prices. This objective underpins the regulation of a sector that has undergone substantial structural changes as a result of the introduction of a competitive market. The key players in the Scottish energy market are ScottishPower and Scottish and Southern Energy who between them own all major non-nuclear power stations, along with British Energy who operate the nuclear stations. The Scottish scene at privatisation was very different from that of England and Wales, since the two non-nuclear companies remained vertically integrated, retaining control of the separate functions of generation, transmission and supply. To ensure diversity of supply they were obliged to provide each other with access to a proportion of their generating capacity. They also were obliged to guarantee a market for nuclear energy from British Energy. With liberalisation of the electricity and gas supply markets coupled with increasingly competitive forces, the companies are aspiring to be multi-utility service companies, rather than simply producers of electricity.

4.6 The mix of power generation in Scotland is diverse. In 1997, nuclear predominated with a 42% share of generation, followed by coal (~29%), gas (~18%), and hydro, renewables and other sources (~11%) making up a total generation of 42 terawatt-hours, which includes electricity generated for export. Total generating capacity is in excess of that required by present demand and Scotland is a net exporter of energy to England and Wales, and exports are planned to Northern Ireland. Primary energy use in the UK in 2000 is forecast to be 10% higher than in 1990.

4.7 Changes in the electricity sector are expected in the near future as a result of market factors, changing subsidies and environmental legislation. The implementation of the European Community Integrated Pollution Prevention Control (IPPC) Directive will force up plant emission and energy efficiency standards by 2007. One implication is that 'combined heat and power' (CHP) plants will be increasingly attractive. Tighter controls on sulphur emissions will come into force, while carbon dioxide emissions are currently under review. In Scotland in 2005 nuclear energy will lose its protection from the market.

4.8 Scotland has one of best potentials for renewable energy in Europe. The UK Government is consulting on an objective to generate 10% of electricity from renewable sources by 2010. One of the main impediments to renewable energy has been its cost relative to conventional generation. The Electricity Act 1989 enables the Secretary of State to require that public electricity supply companies in Scotland buy a specified amount of electricity generated from non-fossil fuel sources. This is termed the Scottish Renewables Order (SRO). The third and most recent SRO, completed this year, led to the award of 150 megawatts in a variety of schemes and will run for 20 years. The SRO is not a guarantee that all projects receiving awards will be viable, though wind power is now capable of producing energy at commercial rates. The planning process, the historical structure of the industry and over-capacity at privatisation have all contributed to the relatively small impact of renewables.

4.9 The offshore oil and gas exploration and production industry is a major employer in Scotland, which contributes direct or indirect employment for up to 170,000 people, and has current capital investment of at least £1.6 billion. Despite the current downturn in exploration, because of the low oil prices, it is likely to continue as a major component of Scotland's economy.

Sensitivity to climate change

4.10 The offshore oil and gas industry operates in an extreme environment. The engineering design of structures is developed to withstand extreme events. For example oil platforms are designed to withstand 1:1000 year waves, which are of the order of 30 metres high. Wave heights close to this specification have occurred west of Shetland. Expert respondents suggested that by the 2050s the evolution of the industry is likely to mean platforms will be floating rather than attached to the sea floor. Such structures are less susceptible to wave damage. The general opinion received was that the physical impacts of climate change are not the major issue for the offshore industry. Other potential, but not yet proven, means of offshore fuel production include offshore wind turbines and tidal barrages. Again, design specifications will reflect the extreme environments in which the structures are situated.

4.11 Onshore production of fuel encompasses coal, of which approximately two million tonnes a year come from two deep mines and a further five million tonnes come from over sixty open-cast mines, and renewable forms such as biomass. Scottish mines are 'wet', in terms of the volume of water pumped per tonne of coal produced, and continuous pumping is required to extract coal. It is not known whether climate change, for example more intense rainfall events, will affect operations. The pollution control of abandoned mine water is of great importance, since the 1995 River Survey suggests it can have a devastating effect on surrounding receiving waters.

4.12 Respondents suggested that changes in climate towards warmer, wetter weather with high atmospheric carbon dioxide levels would be beneficial for growing 'short rotation coppice', enhancing the potential for biomass production. Conversely, a moister climate favours fungal diseases such as willow rust. Willows are currently the most important short rotation coppice species in Scotland, but warmer weather might allow the use of other, higher yielding species. Biomass is relatively expensive compared with other renewable sources such as wind or waste to energy.

4.13 The impact of climate on renewable forms of energy is considerable. Higher and more consistent wind speeds favour wind and wave energy production. More precipitation favours hydro, though it depends on the variability and seasonality of the rain. There are only two pump storage schemes in Scotland while the remaining are gravity-fed. For other forms of power generation, climate is primarily relevant to potential damage of superstructure. Structural impacts on power stations resulting from a change in storminess are unclear and further work may be needed. Since British Energy are responsible for the safe decommissioning of their power stations they adopt a precautionary principle to climate change issues, underpinned by a 'Periodic Safety Review' of each of their stations over a 10 year cycle. The review examines structural coherence of the station to adverse climate conditions, including sea level rise, and makes appropriate recommendations for adapting to change.

4.14 The liberalisation of the energy supply market has led to a proliferation of companies supplying electricity into the transmission network. They will be similarly affected by structural damage to the network. Infrastructure damage already occurs as the events of the Christmas 1998 storms in Scotland showed. At present, the operators consider that future climate projections are insufficiently precise to plan a refurbishment of the entire

infrastructure. The received opinion was that the large cost, which will require Office of Electricity Regulation (OFFER) approval, means further refinement of climate impacts work, as well as further direct experience of weather-induced damage, will be required before companies take action.

Vulnerability to climate change

4.15 On the basis of the present climate change scenarios, the energy sector is vulnerable to sea level rise at coastal power stations. Other vulnerabilities stem from an increase in the intensity or frequency of storms, though evidence for this in the climate scenarios is not clear, and more precipitation and increasingly frequent intense precipitation events. This latter impact will, for example, lead to increased water levels and overflow volumes in reservoirs built to a design specification of a 1 in 10,000-year flood event. Rectifying this would require extensive improvement works on all reservoirs. Earlier snowmelt would also reduce the effectiveness of hydropower into late spring and early summer.

Benefits of climate change

4.16 The major benefit is the increased potential of renewable sources, such as wind and wave power schemes, as mean wind speeds increase. Hydro may benefit from further rainfall, but this will depend on the seasonality of the changes. 'Potential' is not, of course, synonymous with commercial viability. Energy consumption may well fall as a consequence of higher winter temperatures. This will reduce domestic and business heating bills, but could reduce turnover of the utilities.

Adaptation to climate change

4.17 Precautionary design of infrastructure is the norm in the energy industry, for which continual reviews of the necessary climate impacts information are required. Opportunities for renewable energy lies less with the changes in the potential of natural resources than in market changes and Government legislation.

TRANSPORT

Summary: Transport
Climate change presents an important business risk to the effective commercial operation of Scotland's railways. As such, work is underway to minimise adverse impacts and take advantage of any benefits. Flooding and associated problems from excess precipitation is identified as the major source of concern.

Existing infrastructure for shipping and ferry operations is largely robust against the existing forces of wind and tide. The design of new ports, piers and ferries, and alterations to existing ports, piers and ferries will have to take predictions of climate change into consideration. Improved information on storm frequency is vital.

Road operations and infrastructure are particularly vulnerable to increased risk o flooding, which may require a re-assessment of present criteria for drainage systems. A warmer, less windy winter climate is likely to reduce the impact of icing on road damage and transport systems. The physical impact of climate change is not one of the primary factors forcing change in the sector. However, maintaining roads is a substantial expense for local authorities and risk assessments of changing maintenance costs are likely to be required.

4.18 The sometimes severe and always variable weather experienced in Scotland has a major impact upon transport. This section considers the infrastructure involved in the transport of people and goods, including railways, ports and shipping, and roads. While the infrastructure is well developed in urban areas, large regions of Scotland rely on tenuous transport links. Recent episodes of especially severe or unusual weather have raised awareness and concern about how these might be affected by climate change. The Scottish Parliament is expected to shape strategic transport decisions in partnership with the Scottish local authorities. The importance of transport issues has been recognised by the establishment of the National Transport Forum for Scotland and key policy documents including 'Travel Choices for Scotland' and 'NPPG Transport and Planning'. Issues associated with emissions of greenhouse gases are considered in Chapter 4.

Rail

State of the sector

4.19 Railtrack Scotland owns and operates over 4000 km of railway track and associated infrastructure in Scotland. Use of railways by the public and freight is increasing. The sector is in a state of flux with a number of forthcoming initiatives. These include the establishment of a Strategic Rail Authority coupled to Government plans for an Integrated Transport Policy. European legislation for the harmonisation of technical standards for new trans-european networks will be increasingly important.

4.20 Railtrack Scotland has identified weather as a key business risk and is assessing climate change impacts using the UKCIP scenarios. Adverse weather has severe commercial implications, both in lost revenue and capital costs for infrastructure repair. On Boxing Day 1998, Railtrack Scotland experienced as much weather-related disruption as it would normally expect to encounter in two weeks, with 200 trains experiencing delays and £1 million of lost revenue. A comparison of data showing accumulated delay incidents for the years 1997/8 and 1998/9 illustrates the variety and variability of weather related problems (Table 3.1).

Table 3.1: Impact of adverse weather conditions on Railtrack (UK) train delays.

Reason for Delay	**1997/8 (hours)**	**1998/9 (hours)**	**Variation from Previous Year (%)**
Flooding	707	4098	480
Electrical storms	449	510	13
Snow	0	105	
Lineside fires	853	507	-41
Temperature restriction	0	28	
Sea tides	21	24	11
Adhesion (autumn)	1468	2579	76
3rd rail icing	0	106	
Gales	979	538	45

Source: Railtrack Scotland

Sensitivity to climate change

4.21 Railtrack Scotland perceives flooding as a key issue since flash floods can lead to landslides (e.g. Lockerbie in autumn 1998). Consequently, embankment stability is monitored. More intense rainfall events in the future will increase this risk of landslides. Flooding of lines also reduces the stability of the sleepers and bridge structures, halting train operations. Land-use changes have a major impact on rainfall runoff. Developments such as new roads, new housing and golf courses, result in changed runoff patterns while flooding of lines may also be related to agricultural practices. If farmers plough fields at right angles to railway lines, there is a greater risk of water running onto the track. Railtrack Scotland is working with the National Farmers Union of Scotland to encourage farmers to plough parallel to railway lines. Coastal flooding of the rail network is already a problem in certain locations, for example Saltcoats in North Ayrshire.

4.22 High winds interfere with the connection between the overhead lines and the train. Under similar conditions, trees planted too close to lines can cause a hazard because of wind-throw, though when positioned appropriately can protect the infrastructure. Landowners are encouraged to discuss tree planting with Railtrack Scotland.

4.23 Fallen leaves are a major cause of delay and were the largest contributor to delays in 1997/8. Leaves from species such as sycamore and horse chestnut become compacted and can result in failure of clasp brakes. In addition, the wet leaves can short the electrical circuits that provide signalling. Higher autumn rainfall may lead to increased problems with leaf adhesion though new trains include equipment to minimise such problems.

4.24 A rapid succession of cold and warm spells, or a large daily temperature range, tends to put more stress on old and brittle metal lines until they fail, even though lines are heat-stressed to resist extreme temperatures. More ballast is placed on sleepers in summer to prevent buckling. Increased temperature variability, and higher summer extremes, would require increased levels of preparation.

Vulnerability to climate change

4.25 On the basis of the climate scenarios, the major vulnerability of the railways is to further flooding from increased, and more intense, precipitation. Similarly, the impact of higher autumn precipitation on leaves may lead to further leaf adhesion problems. Coastal flooding may increase on low-lying stretches of track.

Benefits of climate change

4.26 Future changes in climate imply a reduction in problems caused by ice and snow. Lower variability in daily and seasonal temperatures would also be beneficial by reducing the heat-stress on track.

Adaptation to climate change

4.27 Adapting to future climate change requires a more detailed risk assessment of the impacts. For example, Railtrack Scotland is identifying sites that are currently vulnerable to flooding and installing pumps and/or culverts. At present rapid response teams are employed to clear drains or divert floodwater away from railways in emergencies. Such reactive emergency response measures are very expensive. The prospect of a significantly changed climate would require a re-assessment of approaches to tackle such emergencies. The rail regulator might in future wish to consider inclusion of additional climate-related costs in the company's expenditure plans. The data from the existing network of sites for measuring river water level near rail track could perhaps be shared with that from the wider networks of the Scottish Environment Protection Agency (SEPA) and others. Other means of responding to climate change include protective tree planting near lines. Planting of more appropriate trees, such as larch or spruce, near railway lines would help alleviate leaf adhesion problems.

Shipping and Ferries

State of the sector

4.28 Ferry services between the Scottish mainland andisland communities in the Hebrides, Firth of Clyde Islands and the Northern Isles, together with ferry services within island groups, form vital trade and communication networks. Elsewhere, ports are also the gateway for a significant component of Scottish trade. Port Authorities operate the major ports around Scotland. Local authorities own many of the smaller harbours. Caledonian MacBrayne, which is a publicly owned company operating ferry services to the Hebrides and around the West Coast, owns about half the piers it uses.

Sensitivity to climate change

4.29 Sea level is the climate factor to which port operations are most sensitive. Scottish harbours and ports can be classified into three groups with regard to their susceptibility to sea level. They are those that are already vulnerable to flooding; those that will become vulnerable to flooding; and those for which sea level rise is unlikely to be a problem. Harbours already vulnerable to flooding are liable to become more so in the future. At one harbour on the east coast, for example, flooding occurs routinely during high spring tides and causes disruption to shipping and to operations in adjacent industrial sites. Areas of a chemical site located in the vicinity are 0.5 m below the spring high tide level. A rise in future sea levels is likely to increase the frequency and extent of such flooding. The loading and unloading of commercial vessels is also sensitive to sea level rise. For example, the Caledonian MacBrayne ferries are designed with an outer-belting, which protects the hull of the ship from the pier. The height of the belting is designed for specific dock-heights. Sea-level rise will exacerbate existing problems of high tides.

4.30 A combination of high tides and storms can lead to abnormally high water heights. Such events are termed storm surges and can lead to heavy flooding of coastal areas. Future increases in sea level and storm activity will exacerbate such events and may present problems for future coastal management.

4.31 Occasionally, harbours may stand to gain from an increase in the mean sea level because ships of greater draught could be accommodated. For instance, the depth of the channel at Aberdeen Harbour is presently limited by underlying rock. In other cases, geographic considerations or the existing layout of ports means that sea level rise and storm surges are not a major problem. For example, the highest known tide at Leith is 13m OD (ordnance datum) while the quay walls and gates are at a comfortable height of 14.2m OD.

4.32 Increasing wind speeds or frequency of storms will affect ferry operations, which are a vital part of the infrastructure of the west coast, Hebrides, Firth of Clyde Islands and Northern Isles. Delays may be extended by the need for replacement crews as permissible working hours are exceeded. The activities of small commercial and leisure craft are also conditional on the weather. For small boats for example, there is a substantial difference between a Force 4 and a Force 6 wind, though most boat users will be familiar with the maritime conditions in Scotland and will take due precautions, with or without climate change. Casual leisure users are more likely to be at risk from more extreme and variable conditions in the summer.

Vulnerability to climate change

4.33 On the basis of the climate scenarios, the net sea level rise ranges to over 0.6m. Such rises are likely to disrupt activities during high tides at vulnerable harbours. The adjustable link spans, which are used to load and unload cargo, are designed to operate within the present tidal range. They will cease to operate as effectively, reducing the time during which operations can be undertaken. However, Caledonian MacBrayne suggest that only their services to Rothesay and Wemyss Bay are curtailed, once or twice a year, due to high tides and higher tides are likely to benefit their operations on small ferry routes, which cannot at present operate at low spring tides. More damaging are storm surges, though there is no clear evidence from the climate scenarios that their frequency will increase.

Adaptation to climate change

4.34 The cost of raising dock heights will be prohibitive at many smaller ports. It is probable that the present small-scale disruption to operations by high tides will increase. Forward thinking is desirable given the reliance of many remote communities in western Scotland on ferry services. Caledonian MacBrayne noted that they would take into account the predicted increase in sea levels when preparing specification for future port works. It is more likely that additional capital investment will be undertaken at larger ports. This will raise structures and penstocks, strengthen seawalls and adapt shifting equipment and cranes. New lock gates may need to be installed. The construction of new sea defences in adjacent areas may be required. Ferries can be redesigned to increase the belting area though this will increase the weight of the boats and reduce their carrying capacity. As ferries are designed for a 20-year life span, though many last longer, it should be possible to introduce new designs to take account of the potential for climate change.

4.35 As a reactive agency, the coast guard will respond to crises. Educational initiatives to raise awareness about future weather impacts could be beneficial, but extremely variable weather is the norm in Scotland already.

Roads

State of the sector

4.36 Road traffic, increased congestion and pollution are expected to be a focus of interest within the Scottish Parliament. In this section we consider solely the physical impacts of climate change. Reduction of pollutants is perceived to be important by road users while the UK Government Climate Change Consultation Paper suggests that reduction of greenhouse gases is also a high priority, through the medium of fuel duty. Issues associated with emissions of greenhouse gases are considered in Chapter 4.

4.37 Scotland has over 53,000 kilometres of public road of which 6% are trunk roads and a further 14% are non-trunk A-roads. Minor roads account for the remaining 80% of roads. The Scottish Executive has responsibilities for the trunk road system, while local authorities deal with minor roads. The physical condition of motorways and trunk roads is monitored by annual condition surveys. These surveys are designed to provide information about the structural, surface and safety condition of the road surfaces. These data are processed annually in a 'Pavement Management' system so as to target available funds on those areas of greatest need.

Sensitivity to climate change

4.38 The road network is particularly sensitive to flooding, as the capacity of drainage systems to remove excess water from road surfaces may be exceeded. Erosion of embankments and landslides may also be exacerbated by intense rainfall events.

4.39 Disruption of road transport also occurs because of snow drifting, icing and frost damage to the infrastructure. Changes in snowdrift patterns are difficult to determine. Icing will become less likely, and reduced variability and range of temperatures will reduce frost

damage. High temperatures can lead to melting of road surfaces and, if they became more common, would require changes in the road surface specification.

Vulnerability to climate change

4.40 With the present climate scenarios, increased intensity of precipitation appears to be the most important impact on road infrastructure and operations. Higher surface temperatures may lead to melting of the road surface, which would require action.

Benefits of climate change

4.41 Reduced icing and frost damage appears likely. Changes in wind direction and strength will change the exposure of roads to snowdrift while the likelihood of less snow-lie at lower altitudes could reduce problems of snow drifting. Reduction of mean wind speeds in winter, coupled to higher mean temperatures, could reduce drifting in some situations.

Adaptation to Climate Change

4.42 The extent to which the current design of roads will withstand future climate change is unknown. Resource allocations to cope with weather-related damage to the road system may have to change.

DOMESTIC

Summary: Domestic
It is expected that housing will be a high profile issue within the Scottish Parliament. Numerous interwoven factors such as poor housing stock, fuel poverty, public health, and energy efficiency will drive change in the sector. Climate change is not one of the key drivers. Nevertheless, changing climate will have an adverse effect on some dwellings, particularly if exposed to increased driving rain, increased storminess, or coastal/riverine flooding. Approaches tackling housing issues in Scotland could beneficially include climate-related issues in their plans.

4.43 The domestic sector comprises of public and private sector housing. There is an expectation that quality of housing and associated issues, such as fuel poverty, will be a high profile issue within the Scottish Parliament. Issues concerned with energy efficiency within households are detailed in Chapter 5.

State of the sector

4.44 Housing is a major source of accumulated wealth and expenditure. There are approximately 2.1 million occupied dwellings in Scotland, of which 1.3 million (62%) are houses and the remainder flats. Post Second World War housing constitutes nearly two thirds of the Scottish stock. The housing sector is undergoing substantial change in response to the driving trends of economic, demographic and technological change. Scottish Homes' documents provide a detailed assessment of likely changes in Scotland's housing needs in the next few years (Scottish Homes, 1997). The Scottish population is expected to remain at around 5 million over the next few decades. Demographic changes will increase the numbers of middle-aged and older people. Economic and social changes will continue to lead to smaller households, and a continued need for new housing stock. Regional differences in housing needs across Scotland are marked.

4.45 The poor quality of some housing stock is widely acknowledged and has ramifications far beyond the climate change sphere. The 1996 Scottish Homes House Condition Survey provides the most up-to-date assessment of Scottish housing. The numbers of dwellings which were judged to be 'Below the Tolerable Standard' in 1996 was about 1% of the total. The ‘Tolerable Standard’ is a set of nine indicators that assess condition or amenity. The most common reason for failing the Standard is associated with rising or penetrating damp. The next reason is inadequate provision of natural and artificial light, ventilation and heating. The failure rate was slightly lower than found by a similar survey in 1991, though the assessments are not entirely comparable. Twenty five percent of dwellings were judged to suffer from some problem of dampness or condensation. Similarly, nearly two in five dwellings were judged to have at least one fault needing urgent repair. Urgent disrepair includes work required on principal roof covers, gutters and down-pipes, flashings, external paint or external wall finish. In addition, over nine out of ten homes were built before the introduction of improved energy efficiency standards.

Sensitivity to climate change

4.46 The expert respondents suggested that though much of the housing stock in Scotland is poor, it is better protected from high winds, cold and wet conditions than stock in England and Wales, reflecting different building regulations. There is some pressure towards harmonisation of regulations within the UK. Currently in Scotland:

- Space of at least 50 mm is required between the inner and outer cavity walls. This allows driving rain, if it penetrates, to accumulate on the inside of the outer wall and trickle down without reaching the inner wall. Unfortunately, this reduces the potential for cavity wall insulation.
- Windows are built behind the outer cavity wall and a damp-proofing course is put between the outer cavity and the timber of the window frame.
- Sarking boards are common. These are timber strips nailed to the rafters giving a solid base for slates, avoiding the need to brace the roof for high winds. The English technique of attaching tiles onto the roof felt via battens is beginning to be used now, as it is cheaper. Builders are required to obtain a certificate to demonstrate that a qualified consultant approved the design with respect to average wind speeds.

4.47 The Building Research Establishment identifies four components of climate that have a significant impact on buildings:

- Temperature. Extremes of temperature generate thermal stresses in building materials. Temperature affects energy use and suitable natural ventilation or, less commonly, air conditioning must be available.
- Wind. High winds cause damage to roofs, walls, windows and infrastructure.
- Rainfall. Driving rain generates problems of rain penetration.
- Sea level. Rising sea levels will lead to more frequent flooding in exposed coastal dwellings. River flooding is also a problem. The recent NPPG 7 on flooding sets out the latest Government thinking on the role of local authority planning and flood risk.

Vulnerability to climate change

4.48 On the basis of the climate scenarios, the housing sector is particularly vulnerable to the expected increases in rainfall. Dampness is a major problem and, for houses with urgent disrepair, is likely to worsen in future. It is not clear whether driving rain will increase markedly. Storms will clearly have an adverse impact but changes in their frequency remain unclear. Sea level rise will have an adverse impact on the relatively small number of exposed dwellings in coastal towns and villages.

Benefits of climate change

4.49 Any reduction in temperature variability will reduce the likelihood of thermal stresses. Warmer weather, in part, will help combat dampness and less energy will be required to heat dwellings to an appropriate level. Summer temperatures in Scotland will probably not reach sufficient levels for air-conditioning to become the norm.

Adaptation to climate change

4.50 For obvious reasons, many individual building regulations have a climate dimension and these could be amended in response to future climate changes. This move would have immediate consequences for future housing stock. However, the turnover of housing stock in

Scotland is of the order of 1% per year. This rate of change implies a very long adaptation period. This suggests that the focus for attention should be on improving the repair of current stock, as well as including future climate issues in existing regulations. Disrepair of housing stock is disproportionately concentrated in the pre-1919 and private rented stock.

4.51 Information important for adapting to future climate includes new maps of the exposure of Scottish housing to rainfall, flooding, sea level rise, and storm frequency on the basis of existing and future climate scenarios.

PUBLIC SERVICES

Summary: Public Services
Local authorities are providers of an extensive range of local services. With tight budgets and numerous competing claims on resources, including environmental improvements under Local Agenda 21, future climate change is generally not a high priority, although at least one Authority, Highland, is considering the local impacts. Future increases in storm or flood damage are clearly detrimental. The existing financial structures militate against a proactive approach to climate change.

The primary drivers in this sector are the implementation of UK legislation and European Community Directives to ensure the supply of high quality water and safe removal o waste water. Reliance on surface water and the time-scale of infrastructure changes ensure that climate change is an important issue for the water authorities.

Climate change is not a public health priority and its impact is likely to be less than that resulting from changes in diet, smoking and lifestyles. The primary vulnerabilities to climate change stem from secondary factors linked to air pollution and increased incidence of diseases associated with warmer temperatures. On the basis of the climate scenarios, incidence of melanoma is likely to be affected by lifestyle changes more than as a result of future Scottish climate. Wetter weather is likely to increase incidence o damp in dwellings leading to further respiratory and associated diseases. The main benefits of climate change will be warmer weather, which is likely to reduce the cold-related deaths in winter and possibly introduce the feel-good factor linked to a warmer climate.

4.52 For the purposes of this report, public services encompass public health, local government (except housing and transport which are covered elsewhere) and water authorities. The full range of activities within the scope of public services is immense and cannot be comprehensively covered in this report. The focus here is on the quality and supply of water, wastewater treatment, general public health issues, and the activities of local authorities in the provision of services.

Local Authorities

Structure of sector

4.53 Thirty-two local councils serve the five million people of Scotland. The councils began operating in their current form in 1996. Local authorities are responsible for delivering a wide range of services to the public. Many of these activities impinge on the environmental quality of their region. This report focuses on climate change rather than the broader themes of environmental improvement encompassed by Local Agenda 21. The recently published 'Changed Days: LA21 in Scotland' details the contribution of local authorities in delivering better quality local environments. Changes in the funding and scope of local authority activities will only become clear with the operation of the Scottish Parliament. The dynamic between the Parliament and local authorities, and the desire for improved quality and more efficient services, are likely to be the main drivers of change in this sector.

Sensitivity to climate change

4.54 Climate-related issues identified by respondents from councils to be of particular concern were impacts on their delivery of services. Of particular importance was storm and flood damage. For councils with a significant coastal region, sea level rise was also an issue of concern. Storms occur regularly in Scotland, and the cost of re-establishing services after storm damage is significant. For example, the cost to clear the landslide that blocked the A83 during the winter of 1998/9, and thus cut off the Kintyre peninsula, was about £2 million. If storm intensity or frequency increases there clearly would be an adverse impact on councils.

4.55 Serious flooding has occurred on a number of occasions in recent years. The causes have been varied, ranging from snowmelt and summer rainstorms to storm surges in coastal regions. Coastal problems will be exacerbated by any rise in sea level, though it is the specific combination of high spring tides and storms, rather than mean sea level rise, that causes most flooding. Other activities that increase the risk of flooding include future changes in land use. For example in the Borders experts noted that in the past poor planning of drainage in new forestry plantations has caused flash flooding.

4.56 Urban authorities noted that the shift towards a 'café culture', was aided by warmer (albeit drier) weather. This spread in shared public space, through leisure activities such as eating and drinking, has positive ramifications for sustaining city centres.

Vulnerability to climate change

4.57 From the preceding discussion it is apparent that the key vulnerabilities of local authorities to climate are associated with impacts that disrupt their provision of services. The most costly of these is storm and flood damage. From the UKCIP scenarios, it appears that more intense precipitation events are likely in future, so exacerbating the flood risk. The potential for increased storm damage is less clear. Some respondents noted the problems arising from increased air pollution as a result of climate change.

Benefits of climate change

4.58 As service providers with little financial leverage to maximise opportunities from climate change, councils foresee relatively few benefits from potential climate change apart from a possible reduction in spending on snow and ice operations.

Adaptation to climate change

4.59 Adaptation to climate change by councils depends on their ability to re-negotiate the allocation of resources from central Government. Councils argued that they require more responsibility for allocating funding to reflect the services they are required to provide in their locality. At present the councils are predominantly reactive to climate events.

4.60 Prior to any substantial expenditure on infrastructure, far better information on the risk of adverse climate impacts is required. At present the experts suggested that climate impacts information is not sufficiently good at a local or regional level to justify expenditure from tight budgets.

Water

State of the sector

4.61 There are three public Water Authorities: North, East and West. They are responsible for the operation and maintenance of all public water supply and waste water systems in their respective regions. Their remit is to ensure the availability and quality of drinking water and the safe removal of waste water. The former is covered by the Water Supply (Water Quality) (Scotland) Regulations 1990, amended in 1991. The latter is regulated by SEPA under the terms of the Control of Pollution Act 1974, and must conform to European Directives and associated UK regulations. Regulation of water quality and, particularly, waste water removal is increasingly rigorous.

Sensitivity to climate change

4.62 In general, water is plentiful in Scotland. Scottish water resources have been considered in detail in the 1994 Water Resources Report. The vast majority of water is derived from surface sources. Only a few isolated areas use burns or wells susceptible to drying up in dry weather. The authorities tend to start the year with full reservoirs so extra rainfall is not necessarily useful. Higher winter season precipitation will lead to higher runoff, which has implications for water quality. The authorities noted that there is a programme for leakage reduction improvements over the next 5 years, limited by public finances.

4.63 Excess surface water can be a problem. Agricultural pollutants may find their way into rivers and lochs, possibly resulting in eutrophication, which is the enrichment of water with nutrients from agricultural runoff or sewage sludge. Higher pollutant discharge into rivers reduces water quality and can lead ultimately to breaches of the European Community Bathing Waters Directive. Retrieving such a situation is expensive. Conversely, low precipitation will lead to low river flows, and a reduction in allowable effluent discharges.

4.64 The waste water system is more sensitive to periods of extreme dry followed by intense downpours. Solids collect during the dry periods and subsequently block the sewers and culverts, which can result in flooding. Similarly, problems of water colouration and dirt from peat following wet/dry periods arise in the north and west of Scotland. Treatment costs are often high because of the remoteness of affected areas and the resulting high cost/customer ratio. European Community standards limiting water colouration are also being enforced.

4.65 The authorities suggested that increasing demands on water resources are being made by the irrigation requirements of agriculture and horticulture in areas such as Fife and East Lothian. A study is underway to assess the sustainability of the largest aquifer in Fife.

4.66 Sea level rise is not a serious problem for drinking water sources, as there are few sources that could be affected by tidal intrusion. However, some combined sewer outflows and storm tanks are sensitive to high tides and may be adversely affected by sea level rise.

4.67 With reduced coastal discharges allowed, following European Community Directives, the storage of waste water is increasingly a problem. Excessive surface water affects this

storage. If the intensity of rainfall events change substantially, then sewers and infrastructure, particularly combined sewer outflows and storm tanks, will require upgrading for compliance with European Community Directives.

Vulnerability to climate change

4.68 Vulnerability to climate change lies with substantial changes in rainfall patterns across the country. There is evidence of changing patterns at present, with slight drying in the east and wetting in the west. However, the resolution of the climate scenarios is too low at present to reliably predict future patterns. Extreme variability of rainfall, or an increase in high intensity events, would require the alteration of the present water system infrastructure. This would be costly for the Water Authorities.

Benefits of climate change

4.69 Regulations on the quality of water are increasing. Slightly higher precipitation without extreme variability, as suggested in the climate scenarios, will continue to ensure a plentiful supply of high quality water to Scotland. In addition, higher precipitation will also ensure the dilution of effluents through higher river flows.

Adapting to climate change

4.70 As public bodies, adaptation by the Water Authorities is dependent on public funding. One Authority reported that the time-scale for rebuilding the waste water infrastructure used to be approximately 60 years. With the Private Finance Initiative (PFI) it is of the order of only 25 years. However, major infrastructure projects are likely to need good regional information about future precipitation patterns. At present such information is not available.

4.71 One long-term option for adapting to climate change with increased precipitation is to export water to England, though this will require a large investment in infrastructure. Other possible adaptations to the present regulations focus on the use of sewage sludge. With the implementation of the Urban Waste Water Directive, sludge cannot be dumped at sea. Landfill is one solution, but is expensive, emits methane and has potential pollution problems with runoff of leachates. Sludge has been used as a fuel in fermenters, though not yet in combined heat and power plants.

Health

State of sector

4.72 Maintenance of public health is the responsibility of the 15 Health Boards in Scotland. The primary issues for public health in Scotland revolve around socio-economic pressures, such as diet, smoking, and communicable and non-communicable diseases. In comparison, climate change is perceived to be of minor importance. A Department of Health study of the impact of climate change on health is underway and will report in 2000. This will provide the most comprehensive assessment of the risks of climate change to public health undertaken in the UK. The results will be compared against present Department of Health priorities.

Sensitivity to climate change

4.73 The sensitivity of public health to direct climate impacts tends to be to extremes of cold or heat or, particularly in Scotland, to pervasive dampness in dwellings. Changes in these extremes will affect peoples' health. The climate scenarios suggest that extremes of cold in winter will reduce, while warming in all seasons will increase. Variability of summer temperatures may rise leading to more extremely hot days. The experts suggested that the reduction of cold-related deaths may outweigh the increase in heat-related deaths in Scotland, but the climate scenarios are not sufficiently precise to quantitatively assess such changes.

4.74 Other direct impacts of climate change include changes in incident short-wave radiation, leading to changes in the incidence of melanoma (skin cancer). However, the experts felt that existing leisure patterns, such as holidays to the Mediterranean, were more likely to affect incidence of melanoma rather than the Scottish climate. The experts also noted the positive psychological impact of warmer, sunnier weather on the population.

4.75 Of greater concern are the secondary effects of climate change, such as increases in haze and photochemical smog caused by a combination of pollutants and stratified air. Warmer temperatures, particularly in summer, or less well mixed air, suggested in winter and spring by the lower mean wind speeds, will contribute to poorer air quality when in conjunction with air pollutants. This may result in more cases of asthma, allergenic disorders, and cardio-respiratory diseases.

4.76 Other secondary effects suggested by the experts included the possible increase in diseases transmitted by micro-organisms, insects and other 'vectors', which may proliferate in a warmer, wetter climate. For example, infections resulting from food poisoning may increase as a result of hotter summer weather.

Vulnerability to climate change

4.77 The primary vulnerability of public health to climate change in Scotland appears to be associated with the secondary impacts of increased air pollution and increased transmission of food-related diseases associated with warmer temperatures. For example, the incidence of childhood asthma may rise as a result of poor air quality. The climate scenarios suggest that incident short-wave radiation is unlikely to increase markedly, so an increase in the incidence of melanoma is unlikely to be caused by Scottish climate change.

Benefits of climate change

4.78 Benefits will be observed from mean increases in winter temperatures, which will reduce cold-related deaths. Similarly warmer and sunnier weather, which may occur in spring and to a lesser extent in summer, may create a feel-good factor. Nevertheless, the experts noted that any benefits from climate change are unlikely to have a major impact on public health in the absence of changes in the non-climatic causes of morbidity and mortality in Scotland.

Adaptation to climate change

4.79 Health education could assist in informing people of the implications of climate change, but social and economic pressures remain to be overcome. The experts noted that the

perception of health risks by people is rarely associated with actual risk. For example, the media tend to focus on items such as *E-coli* or drug-related deaths, which belies the importance of diet, smoking, lifestyle and chronic diseases. It would be possible to learn from analogous situations, such as the Australian approach to tackle the incidence of melanoma.

BUSINESS

Summary: Business
The service industry, which contributes two thirds of Scotland's GDP and three quarters of its workforce, is, in general, less sensitive to the direct impacts of climate change than other sectors. Relationships between business operation and the impact of climate change on market share are currently highly tentative and disentangling the influence other socio-economic changes makes identifying causal relationships problematic.

The vulnerabilities of the manufacturing industry and tourism are similar to those identified in the energy, transport and domestic sectors. Benefits depend on the particular business operation. Of far greater concern to the expert respondents is the impact of measures to reduce carbon dioxide emissions, discussed in Chapter 4.

4.80 In 1997 there were nearly 300,000 enterprises in Scotland, of which 2000 are large, with over 250 workers, employing a total of over 720,000; over 3,000 medium-sized enterprises with a total workforce of over 230,000; and the remaining small enterprises with under 50 workers and a total workforce of over 800,000. In 1995, the sectoral contributions to the Scottish GDP were as follows, with a total of approximately 75% of workers based in services out of a total employment of about 2 million

Agriculture, Forestry, Fisheries	3.2%
Mining, quarrying, oil & gas extraction	2.3%
Manufacturing	20.1%
Electricity, gas & water provision	3.7%
Construction	6.5%
Services	64.1%

4.81 In general terms, the economy of Scotland (like that of the UK) has moved away from manufacturing and towards services (including retail and finance). Services are, in general, less sensitive to the direct impacts of climate change than manufacturing. The key climate issues are the impacts of temperature, rainfall and wind upon the buildings in which service functions are conducted. Working conditions in such buildings could become adversely affected in high summer temperatures, reducing morale and productivity, whilst driving rains could necessitate higher levels of routine maintenance. Air conditioning to alleviate higher working temperatures results in more carbon-dioxide emissions and higher energy bills. Indirectly, the impacts of climate change might be more significant through changing structures of market demand. For instance, people tend to consume different kinds of products in different weather conditions and in different seasons. More fruit and vegetables are sold in the summer and beer sales rise in hotter weather, whilst clothing and footwear sales go down during hot dry summers. Any such relationships are currently highly tentative and disentangling the influence of other socio-economic changes makes identifying causal relationships problematic.

4.82 This section considers some general climate-related issues in the manufacturing industry and insurance business and focuses on tourism. The Advisory Committee on

Business and the Environment (ACBE) produced a report last year entitled 'Climate Issues for Business'. Its summary findings for climate impacts were that individual businesses should explore the available climate scenario information and take appropriate steps to manage their response. Issues associated with means of reducing greenhouse gas emissions from business are explored in Chapter 5.

Manufacturing industry

State of the sector

4.83 Manufacturing is a major employer in Scotland and manufacturing processes can have a profound impact on the local environment. Pressures for change are market driven or reflect the increasing environmental standards being legislated. The key sectors are shown below:

Sector	Employment (%)	Contribution to Manufacturing Output
Food, drink & tobacco	19.4	20.2
Textiles, leather, footwear, clothing	12.4	5.3
Pulp, paper, printing & publishing	9.8	7.2
Minerals	3.5	8.4
Chemicals & man-made fibres	4.5	5.1
Metals & metal products	9.2	6.3
Mechanical Engineering	7.9	6.3
Electrical & instrument engineering	16.7	29
Transport Equipment	6.9	5.3
Other	9.8	6.9

4.84 The decline in heavy industry has been countered by a rise in new technologies – in particular electronics and electrical and instrument engineering has grown considerably in the last decade. Scotland is now one of the major European centres for production of semi-conductors, computers, work stations and automatic telling machines, producing 38% of Europe's branded computers.

Sensitivity to climate change

4.85 Increasing temperatures will have an impact upon the effectiveness of cooling processes in the manufacturing sector. At one chemicals site in Scotland, there is already a decrease in throughput for some processes in very hot weather. The material from one process does not condense at high summer temperatures with consequent reduction in process efficiency. The industry can respond to such problems on a case-by-case basis. For example one company modified their fans to increase cooling, at a cost of several million pounds. The requirement for more cooling facilities has to be analysed in the wider context of plant re-design and the need to maintain flexibility for re-designing processes and products in the light of rapidly changing market demands. The existing lifetime of current manufacturing plant is

a further factor in calculations. There is obviously less incentive to modify manufacturing plant that will shortly be replaced.

4.86 Semi-conductor manufacture occurs in highly controlled internal environments that are already air-conditioned. An increase in air temperature would require additional cooling requirement, though the extra costs are relatively small. Other computer and electrical equipment manufacture is less sensitive to temperature. The life-time of the computer industry plant, however, is relatively short given the extremely rapid rates of technological and market change. Hence, the sector could respond incrementally to the change in climate impacts.

4.87 The food and drinks sector is an important part of the Scottish economy and climate change will be important in influencing the availability of particular ingredients. It may become possible to source more ingredients locally due to changing growing conditions, though increased autumn rainfall could cause operational problems of extracting crops and could increase the potential for decay. Food and drink production takes place in a temperature-controlled environment. In hotter summer weather, the energy bill for refrigeration and air conditioning may increase. The markets for food and drinks may well change in a changed climate (for example an increase in the proportion of foods to be eaten cold) though most food processors could respond relatively rapidly to such changed demand patterns.

4.88 Some chemical and pharmaceutical firms could face the problem of increases in emissions of Volatile Organic Compounds (VOCs) during hotter weather. This would have implications for occupational health and safety and would require ameliorative action including, for example, deployment of VOC abatement technology.

4.89 Some industries such as paper manufacture, food processing and information technology component production and assembly, require large volumes of water, though the sector is working to reduce the water requirement. There is generally ample water available at Scottish sites, so respondents to the study considered that water shortages would not become a major problem in the next few decades.

4.90 Industrial treatment and facilities for processing waste-water may be influenced by changing precipitation patterns. Treatment facilities are designed to cope with a particular extreme rainfall event, for example a 1:2 or 1:5 year rainfall event. If the capacity of the waste system is exceeded a diverting system of drains operates at many sites, which involves only a rudimentary level of treatment. The Scottish Environment Protection Agency has to agree upon the procedures for diverting this excess waste water and has to be informed when diversion occurs. An increase in winter and autumnal rainfall will increase the likelihood of current waste water treatment capacity being exceeded. Redesign of waste water treatment facilities may well be required as a consequence. One response is the construction of larger storm water storage tanks, though these incur large capital and operating costs.

4.91 An increase in summer temperatures in Scotland may lead to poor working conditions in some facilities and sites. A peak in electricity use occurs in Edinburgh in the summer because of air conditioning, though this is likely to be influenced by social trends and the volume of heat-generating computer equipment. The higher winter temperatures may improve working conditions in factories and work sites which are not presently well insulated.

4.92 The insurance industry has been particularly active in the debate over climate change. The issues for insurance are reasonably well documented: subsidence in areas with clay soils (not a major issue in Scotland); inland river flooding; coastal flooding; and damage to buildings from storms and high winds. River flooding is a serious risk in Scotland. The role of the Scottish Environment Protection Agency in the planning process is limited to providing information/advice, when requested, to the planning authorities. This reduces the opportunities for SEPA to deter development on river flood plains. Damage from coastal intrusion is a localised risk. Many buildings in Scotland are designed to withstand higher wind speeds than buildings in England.

Vulnerability to climate change

4.93 General vulnerabilities to climate change for business reflect similar concerns over storm and flood damage reported in other sectors. Rising temperatures and changing rainfall patterns may affect some manufacturing operations.

4.94 More weather-related insurance claims could affect the performance of the insurance sector, though yearly adjustments allow rapid response to changed profitability. In addition, the financial sector in Scotland could conceivably be affected by the impacts of climate change on investments and insurance claims in other parts of the world.

Benefits of climate change

4.95 The primary benefits concern reduced energy costs and frost damage in winter.

Adaptation to climate change

4.96 Climate change issues rarely influence business decision making, which is predominantly driven by the market. Nevertheless, infrastructure will need to be designed to withstand future climate change. Some sectors are likely to be more responsive to climate change than others, particularly if their market sector requires a rapid turnover of product. Compared to many other sectors, most businesses can respond to the impact of climate change flexibly and incrementally.

4.97 Other trends and drivers in the insurance industry will influence the sector, increasing the significance of climate change. For instance, if the move towards more individual accountability observed in car insurance extends to house insurance, it may increase the significance of flood and storm damage risk. This would, arguably, provide an incentive for more rational planning decisions in the future with respect to development in higher risk areas, but equity issues will certainly arise with respect to the owners of existing property. The further extension of geographically-based expert information systems will provide insurers with a much better data base on relative flood risks, which could support moves towards differentiation of insurance.

Tourism

State of sector

4.98 Tourism is one of the most important industries in Scotland, employing 1 in 12 of the workforce (1 in 8 in the Highlands and Islands). In 1997, tourists spent nearly £2.7 billion and filled over 13 million bed-nights in Scotland. The Scottish tourist season is generally compressed into a short summer season; 50% of visitors come in just 12 weeks of the year. The Scottish Tourist Board (STB) considers that the seasonal nature of tourism is the industry's main weakness. Unless more potential visitors believe that Scotland is a year round destination, growth in tourism will be limited. Tourism is clearly influenced by weather conditions. A change in climate will influence perceptions of the attractiveness of Scotland as a tourist destination. It is difficult not to conclude that the weather is an important reason why the tourist season is limited to the late spring and summer. Hence, critical climate-related issues include the extent to which climate will influence the maintenance or extension of the current tourist season.

Sensitivity to Climate Change

4.99 The increase in temperature throughout the year is likely to improve the attractiveness of Scotland as a destination for most tourist activities, with the exception of winter sports. A more critical issue, perhaps, is changing patterns of rainfall. Increasing rainfall is likely to be detrimental to tourism, particularly in summer months. Conversely reducing rainfall will be beneficial. The scenarios suggest no clear changes in summer rainfall and a small reduction in the spring. Larger increases are suggested in autumn and winter, and for later next century. This pattern could influence the extent to which the tourist season can be extended.

4.100 Winter sports, particularly the ski industry which is economically marginal, are perhaps most at risk from winter warming. However, the climate scenarios cannot provide sufficiently detailed information to assess future changes in snow-cover at higher altitudes and across complex terrain. Snow-lie at low altitudes is likely to reduce. High winds are an important factor for the operation of ski centres and the climate scenarios suggest little change in the seasonal average wind speed. The variability of winter temperatures is likely to decrease, but without more detailed climate information, it is not clear how this will impact the viability of the ski industry.

4.101 The current level of tourism in Scotland operates within the perceived weather conditions. Some in the industry argue that climate change will have little, if any, impact on tourism. In support of this argument, growth in tourism in recent years has been concentrated in the short-break market (2-3 days away), which tends to occur in the cities rather than rural areas. The move towards greater mobility over longer distances, combined with lifestyles that favour shorter, more frequent holidays, implies that the short break market will continue to grow. Furthermore, many tourists are passive viewers rather than actively engaged in outdoor pursuits. The impact of poor weather is consequently less profound. Climate change will affect those engaged in active pursuits in different ways.

4.102 Surveys by the STB suggest that the most commonly quoted 'unattractive feature' of Scotland is 'poor weather'. Conversely survey figures suggest that whilst visitors may not expect good weather, and hence accept the present weather conditions as the context for visiting Scotland, it does not mean that they would not prefer the weather to change. Some

visitors actually find the maritime climate of Scotland appealing, but the 'scenery' is consistently top of attractions.

4.103 At present, it would appear that the domestic tourist market in Scotland is partially weather dependent, while the international market is less so. It may be that as climate changes, the character of tourism and of tourists visiting Scotland may also change, so that the sensitivity of specific activities to weather on the present industry is not the only relevant factor. Studies of tourism consistently show that there are multiple influences upon the sector and only rarely do single variables assume a high level of significance.

Vulnerability to climate change

4.104 Substantial increases in rainfall are likely to be detrimental to tourism. However, the projected seasonal patterns of change with drier spring and similar summer rainfall amounts are likely to minimise this impact. Socio-economic changes are likely to prove more important influences.

Benefits of climate change

4.105 Increased warmth will help to encourage visitors, but other influences are likely to dominate over any climate-induced change in the industry.

AGRICULTURE, FORESTRY AND FISHERIES

Summary: Agriculture, forestry and fisheries
The management of Scotland's natural environment resources is perhaps the sector most affected by climate impacts. Climate impacts are likely to be predominantly beneficial to forestry through increased growth rates, but increased frequency of windstorms will be detrimental. Fish are sensitive to any change in climate that affects the marine or freshwater environment. There is quite compelling evidence that recent declines in both migratory salmon and some marine species may be linked to fundamental changes in the ocean circulation that appear to be occurring around Scotland. If these changes continue they could have a serious impact on fisheries, but any risk assessment is hampered by the scarcity of data on marine climate trends. Agriculture is dominated by subsidy payments, which insulate the farmers from some detrimental climate impacts. Operational difficulties from waterlogged ground could increase. However, a longer growing season could lead to more diverse and valuable crops.

4.106 This sector focuses on those industries associated with primary produce: fishing, forestry and agriculture. Scotland has a strong cultural and social identification with its primary producers. Land use change and rural affairs are expected to be high on the agenda of the Scottish Parliament. Productive seas surround Scotland and fishing has long been an important economic activity, shaping the development of many towns and cities. The sport of fishing for salmon in Scotland's rivers is world renowned, and is an important attraction to overseas visitors. Moreover, the salmon symbolises the pristine quality and wild nature of the Scottish environment. Fishing, forestry and agriculture are valued sources of employment and income in rural parts of Scotland, and are therefore an essential element of a sustainable rural economy.

Fisheries

4.107 The discussion will concentrate on the most economically important fisheries: the marine fisheries of the North Sea and North Atlantic; the freshwater salmon and sea-trout fisheries of Scotland's rivers; and the aquaculture industry, farming primarily salmon but also trout and shell-fish.

State of the sector

4.108 The major issue faced by both freshwater and marine fisheries is the decline in fish stocks. In recent years salmon and sea-trout numbers have fallen, particularly in the rivers of the west coast of Scotland. The stocks of most of the commercially exploited species of sea fish are close to, or outwith, safe biological limits. There are many possible causes, which include over-fishing, pollution, eutrophication (enrichment of water with nutrients from, for example, agricultural runoff or sewage sludge), acidic runoff from forestry and changes in predator numbers. Another possible cause that has come to light recently is changes in ocean currents: these can affect the amount of food available to adult fish, and disrupt the normal

pattern of dispersal of larval fish to the main fishing areas. Over-fishing is generally considered to be the major cause of the decline in the sea fisheries. As a result, the industry is now heavily regulated by the Common Fisheries Policy of the European Union, under which Total Allowable Catches and quotas are agreed annually for the commercially important species of the North Sea and Atlantic.

4.109 The recent decline in wild salmon and sea-trout has been most pronounced on the west coast of Scotland, where there is circumstantial evidence linking it with the salmon farming industry. The farmed salmon are grown in cages, submerged in sea-lochs, in high densities and are prone to infection. There is a consensus amongst fisheries researchers that caged salmon can act as a source of infection of parasitic sea-lice for migratory wild fish. A further problem is the escape of farmed fish, which may breed with the wild population, making them less well-adapted to the local environment. There are several other factors that also reduce the survival of salmon at sea, including net fisheries; accidental "by-catch"; salmon fishing around Greenland and the Faroes; increasing seal numbers; and changes in the abundance of food species. Fish farming faces increasing concerns over its environmental impacts, particularly water pollution, eutrophication and landscape considerations. Further expansion of the industry is likely to be limited by the availability of suitable inland sites, where planning consent has to be gained for new developments. Planning consent also has to be obtained for off-shore site developments from the Crown Estates Commissioners. Currently, the spread of the disease Infectious Salmon Anaemia is causing much concern.

4.110 Both the marine fisheries and aquaculture sell their products into a global commodity market, so they are sensitive to fluctuations in world prices, caused by natural variability (changes in fish abundance) or economic factors (such as changes in the economy of the Soviet Union). The products must be transported long distances, often from remote areas of Scotland, to the major markets in south east England and Europe. Transport costs therefore have a significant impact on profitability.

Sensitivity to climate change

4.111 Predicting the impacts of climate change on fisheries is complex. Fish are sensitive to many attributes of the physical (water temperature, salinity, oxygen concentration) and biological environment (food sources, predation, diseases, competition with other species) that may be influenced directly or indirectly by climate. Their sensitivity to these attributes often changes as they pass through the different phases of their life cycle. Many fish species undertake annual migrations: salmon and sea-trout spend part of their life cycle in freshwater and part in the sea, so are affected by changes in both these environments. Fish can only survive in water over a limited range of temperature. The upper and lower limits of the temperature range vary between species, and are one of the factors that determine geographical distributions. Temperature also affects the growth rate of fish, by altering the efficiency of conversion of food into body tissue.

4.112 In the seas around Scotland, water temperature depends primarily on the pattern of ocean currents, which determines whether the water has originated from warmer waters further south or from cooler arctic areas. In addition to the direct physiological effects on fish, water temperature also affects the productivity of food species. Changes in ocean currents could therefore have serious effects on fish populations. Higher temperatures cause reduced concentrations of dissolved oxygen in water, resulting in increased stress for fish.

Lack of oxygen is most likely to be significant in freshwater lochs and the lower reaches of rivers, particularly in areas affected by eutrophication.

4.113 Changes in rainfall are likely to have their greatest impact on river fish. Increased winter rainfall associated with storms, causes flooding which can alter the depth and position of river channels, damaging fish habitat and removing salmon eggs from the river bottoms where they are laid. In summer, lower rainfall would reduce the "wetted area" of river systems, decreasing feeding habitat and oxygen concentration.

4.114 Storms and high winds have a direct impact on the activities of fishermen. Days at sea may be lost while boats must remain in harbour, and boats may be damaged. Bad weather also prevents routine husbandry tasks on salmon farms, and damages cages. Feeding of the salmon may be prevented, reducing growth rates and final production. Changes in sea level are most likely to affect estuarine areas, causing changes in the extent of inter-tidal areas, depending on the amount of hard engineering undertaken to prevent inundation of low-lying coastal areas.

Vulnerability to climate change

4.115 The UKCIP scenarios used by the present study do not include predictions for seawater temperatures. There is, however, convincing evidence that changes in ocean currents are occurring (Turrell, 1998) and that these might be contributing to the decline in wild salmon by reducing their survival at sea. In the rivers, higher temperatures and lower oxygen concentration are unfavourable to salmon, sea-trout and trout, and might tip the competitive balance towards less valuable coarse fish, such as pike, allowing both native species and those introduced by anglers to extend their ranges.

Benefits of climate change

4.116 The aquaculture industry could benefit from higher growth rates caused by increased water temperature, though this might also favour pests and diseases. Farming of different species requiring warmer water might become possible. Increased summer rainfall might allow salmon to enter the rivers more quickly, avoiding netsmen and predators.

Adaptation to climate change

4.117 Change in rainfall pattern is already apparent, with higher mean and peak river flows, particularly in west coast rivers. Future change requires better management of river catchments and river bank habitat for salmon. A closed season in spring for salmon fishing with rods or mandatory catch and release regulations could be introduced. These measures might reduce the number or anglers, and therefore have a negative impact on the income to the rural economy from spending on accommodation and local services.

4.118 At sea, switching the fishing effort to new (warmer water) fish species is possible. The fishing industry is inherently adaptable, but there can be significant costs associated with re-equiping boats to catch different species. There is scope for improving models of fish populations, which should explicitly account for the impact of possible changes in the ocean

circulation on food sources and the dispersal of fish larvae. This in turn would improve the information available to set Total Allowable Catches.

Forestry

State of the sector

4.119 The Forestry Commission is responsible for advising the Government on forestry policy and implementing the policy in Great Britain. It is comprised of two agencies; Forest Enterprise, which manages forests and woodlands owned by the nation, and Forest Research, which informs the development of forestry policies and practices. Remaining forests are owned privately. Nearly 9 million cubic metres of wood are supplied by British forests and this will rise to 15 million cubic metres by 2020. About 85% of the national requirement for timber, paper and other wood products are imported into Great Britain each year.

4.120 Agricultural policy is both the main driver and control on the conversion of agricultural land to forestry. Farmers who receive less income after changes in the European Union Common Agricultural Policy may convert to forestry. For forest companies, the availability of land will be the main limitation. Timber prices from the Baltic States are very low at present, which has a major effect on the profitability of Scottish commercial forestry. Access to the countryside is a continuing and significant driver of forest use policy both for the commercial production sector and for rural land use more generally. The need to make the countryside attractive for tourism and sport is extremely important at present.

Sensitivity to climate change

4.121 The expert respondents suggested that temperature is probably the most important variable to affect forest growth and that variability of summer/winter temperatures is of greater importance than average temperature. Changes in rainfall and the consequent soil moisture regime may be significant in south east Scotland but is of less interest elsewhere because of the high existing rainfall, though waterlogged ground may become more common particularly in autumn and winter. Excess wind has a major negative impact on forests while higher atmospheric carbon dioxide concentrations are likely to improve growth rates. The key uncertainty in the likely response of forestry to climate change is the variability and rate of change in climate.

Vulnerability of climate change

4.122 The most serious risk to forestry from climate change appears to be the possibility of more extensive wind-storms leading to more blow-down and limitation of tree height. Other negative impacts to forestry that have been suggested include insect damage and associated factors if temperature gain exceeds particular thresholds. The respondents suggested that without better information on climate variability it is difficult to quantify any of these impacts.

Benefits of climate change

4.123 Climate change is likely to be beneficial to all types of forestry in Scotland. The commercial sector will benefit from increased growth rate, resulting in shortened rotation times. There was some doubt as to the size of this benefit, with the forest industry suggesting

an improvement of only 10%, whereas academics were more optimistic. Benefits may also accrue to commercial forestry by the possibility of using a wider range of species, which could generate more valuable products. Non-commercial woodlands would benefit from enhanced species availability, which could help to make more attractive woodlands for recreation and sport. A wider range of broad-leaved forests would be better able to supply appropriate wood for local craft industries. Such improvements to forests would have potential to enhance the viability of rural communities.

Adaptation to climate change

4.124 The time scale of adaptation is likely to be several decades because of the long-term nature of tree growth. The public and private forest industries believe they have the management systems and knowledge to respond to future changes in climate.

Agriculture

Present state of the sector

4.125 Nearly four fifths of the total land area of Scotland is used for some form of agriculture, of which the vast majority is rough grazing. The average size of holdings in Scotland is significantly larger than in the UK or EU. This reflects the large proportion (85%) of agricultural land classified as Less Favoured Areas (LFA).

4.126 The agriculture workforce was about 59,000 in 1997, or 2.5% of total Scottish employment and about 8% of the rural workforce. Agriculture is also responsible for maintaining jobs in upstream and downstream industries such as agricultural supplies and food processing.

4.127 The harsh climatic and soil conditions which apply in much of Scotland, tied to remoteness from main markets, makes viable and profitable farming a difficult task. The support framework provided by the Common Agricultural Policy, both in direct and indirect terms, is a vital component for the majority of producers to maintain income levels. At present, low commodity prices, the strength of sterling, competitively priced imports and the ban on export of British beef, leave farmers facing an uncertain future.

4.128 Public perceptions of the agricultural industry are changing.). In Scotland, particularly in the uplands, there is an increasing expectation that farmers act as guardians of the landscape.

Sensitivity to climate change

4.129 Scotland has a wealth of resources investigating the science of agriculture and terrestrial ecosystems, such as the Scottish Crop Research Institute, the Scottish Agricultural College, the Macaulay Land Use Research Institute and the Institute of Terrestrial Ecology. This brief review cannot provide a comprehensive review of the detailed work being undertaken.

4.130 There have been few truly integrated studies of the effect of climate change on agriculture in one region. An existing study funded by MAFF, under the UK Climate

Impacts Programme umbrella, is an integrated study focusing on two sites NW England and East Anglia and the results will be available next year. A Scottish Office funded study in the early 1990s provides another example and provides the basis for some of these comments.

4.131 Many results from the study suggest that climate change in Scotland needs to be larger than projected over the next century for it to become the major driver in modifying agriculture. Individual components of agricultural systems appeared inherently robust and adaptable. The effect of climate extremes on agricultural production has yet to be fully understood. The study also revealed inherent difficulties in attempting to link models ranging from process-based simulation models of crop growth to regional changes in crop viability. Key sensitivities included temperature and precipitation effects on crop growth, disease, forage quality, and the working practices of farmers.

4.132 In general, water stress is not a problem in Scotland, apart from areas of the south east and with specific crops such as potatoes, which have a high water-demand. Waterlogging is a bigger problem for many farmers. In the autumn of 1998, many fields of potatoes could not be harvested because of operational difficulties associated with waterlogging.

4.133 A longer growing season will lead to increasing diversity of crops, with the potential for higher value crops, such as fodder maize, sugar beet and increased areas of oil seed rape.

Vulnerability to climate change

4.134 The key vulnerability appears to be to increased variability in the climate system, whether temperature, precipitation or other variables. Difficulties of access to waterlogged fields are likely to increase, particularly if the large increase in autumnal rainfall occurs. Nevertheless, economic and social factors remain by far the most important driver on the sector.

Benefits of climate change

4.135 As above, the regional patterns presented by the climate scenarios are too coarse to reflect the variability in soils and daily weather that have the most impact on agriculture. In general, a warmer climate will assist in increasing the diversity of crops, such as increased volumes of vegetable crops, sugar beet, fodder maize, and more oil seed rape. This would leave farmers less dependent on one commodity and therefore more insulated against the market. Warmer winters with less variability, and less spring rainfall, may assist livestock production.

Adaptation to climate change

4.136 The sector is adapting to forthcoming changes in the Common Agricultural Policy, Agenda 2000, incentives such as ‘Set Aside’, public perceptions of food safety and environmental concerns, and market factors. Climate change is less of a major concern in comparison.

CHAPTER FIVE MITIGATION OF GREENHOUSE GAS EMISSIONS

INTRODUCTION

5.1 This chapter reviews possible strategies for reducing the emission of greenhouse gases in Scotland. The Kyoto Protocol on Climate Change commits developed countries to a legally binding reduction in greenhouse gases by 2008-2012. The European Union must reduce emissions by 8% (the EU 'bubble'), with the UK taking on a target reduction of 12.5%. The UK must therefore reduce its emissions from the baseline at 1990 of 216 MtC (million tonnes carbon equivalent) to 189 MtC per year averaged over 2008-2012. The Government aims to reduce emissions of carbon dioxide by further than required by the EU-agreed target to 20% beneath the baseline. The DETR prepares the annual UK greenhouse gas 'Emissions Inventory' and is exploring how the inventory could be disaggregated to component countries of the UK. The respondents welcomed a greenhouse gas inventory for Scotland, but opinion was divided on whether Scottish targets for greenhouse gas emission reductions should also be devised. Possible policy implications for attaining the Kyoto Protocol targets and beyond have been discussed in depth over the past year, particularly through the UK Climate Change Programme Consultation Paper (DETR, 1998). In essence, the question is how to move to a low carbon economy without impairing competitiveness, whilst maximising the opportunities and benefits of change. This chapter seeks to outline the policy implications rather than explore them in any depth. It sets out the primary topics for each sector, in order to provide a comparative assessment of the relative importance to different sectors of direct climate impacts and strategies to reduce emissions.

5.2 This chapter considers the five most significant sectors: energy, business, transport, domestic, and land use. The following topics are reviewed briefly:

Energy
- Mix of fuel for power generation
- Regulating emissions from power stations
- Energy services

Business
- Energy tax
- Trading mechanisms
- Energy efficiency

Transport
- Taxation
- Rural issues
- Congestion/pollution

Domestic
- Thermal quality of housing
- Information and incentives
- Domestic appliances and energy efficiency

Land Use
- Land use change
- Forestry

ENERGY

5.3 Options for reducing emissions from the energy supply sector depend on the changing mix of fuel used in generation, regulating emissions from and efficiencies of power stations, and the further development of energy services for customers.

5.4 Nuclear power contributes approximately 40% of the energy generated in Scotland and Hunterston B is currently scheduled for closure around 2010. As nuclear energy is not a primary contributor to greenhouse gas emissions, its replacement by any carbon-intensive fuel will substantially increase emissions from the sector. It is not clear at present which fuel will replace nuclear. The recent 'dash for gas' is being restrained though gas remains commercially attractive, while renewables have enormous potential in Scotland, but it is not known whether there is sufficient commercially viable capacity, in the next 20 years, to replace nuclear. At present, many wind and hydro projects can compete commercially. There are also technical limitations to the proportion of network energy that can be supplied by 'embedded generation' such as wind power, though there is a long way to go before that limit is reached. Biomass and waste fuel would appear to have a strong future, though they are emitters of carbon dioxide, but if they replace the use of fossil fuels they have the potential to approach carbon neutrality. The recent Scottish Renewables Order has also approved its first wave power scheme. The UK Government aims to generate 10% of UK energy from renewables by 2010, though in Scotland over 10% of energy is already supplied by renewables. This leaves a substantial shortfall when nuclear comes off-line, assuming that demand remains the same. The industry prior to privatisation was characterised by over-capacity, consequently, the marginal cost of generating further power from existing stations is below that of developing renewables. As the generation mix changes and renewable energy technology develops there may be greater opportunity for renewables to compete on a level playing field with conventional generation.

5.5 The continued implementation of tough environmental legislation will affect the energy generation fuel mix. In particular, the introduction of the IPPC Directive will require plants to achieve higher standards for emissions and energy efficiency by 2007. In addition to moves to tighten limits on sulphur dioxide emissions, this may well have an adverse impact on coal-fired stations, unless it is economically viable to fit emission abatement technology. The EC Integrated Pollution Prevention Control (IPPC) Directive may encourage the development of combined and heat power (CHP) plants, which are more efficient.

5.6 Companies are aiming increasingly to provide 'energy services'. This involves a more responsive interaction with customers to provide more choice and flexibility in energy supply. Examples include supplying energy efficiency measures and advice or by providing customers with the option to choose renewably-generated energy. This latter approach currently employs a green tariff, which has had a very low uptake. Respondents suggested that, at present, Government regulations make it difficult to supply such services to domestic customers. Companies will maximise opportunities within the regulatory framework, but respondents sought a clear understanding of the future direction of policy.

TRANSPORT

5.7 Possible measures to reduce greenhouse gas emissions from the transport sector include influencing a change or reduction in demand for vehicle use, developing a more efficient transport system, or improving vehicle and fuel technology.

5.8 A means of reducing demand, or forcing a switch to other forms of transport, is taxation on fuel. Expert opinion is divided on the elasticity of demand for vehicle use with fuel price. A common view amongst respondents was that vehicle use was not particularly sensitive to fuel price, but that the policy was easy to implement. Others consider that fuel price needs to rise dramatically to obtain a tangible reduction in vehicle usage. Some public transport organisations look with favour upon the fuel price escalator for private cars as an incentive to switch to public transport. Even these organisations acknowledge the negative perception of such measures by the wider public. Not surprisingly, road haulage firms are against further rises in fuel price and point to the danger of the relocation of firms to continental Europe. Many small and medium-sized enterprises (SMEs) are relatively more sensitive to fuel price levies than larger firms. They cannot, for instance, negotiate cheaper fuel prices through bulk-buying and storage facilities.

5.9 Experts contributing to the study asserted that there is a strong feeling in the rural regions that increasing fuel prices have a disproportionate effect there since alternative transport is not available. Respondents also commented that there is a need for flexibility when designing an emissions strategy that reflects different geographies and opportunities for action, such as the Scottish Executive scheme to support rural petrol stations. The recent study by the Scottish Office on Rural Petrol Stations makes clear the difficulties for inhabitants and businesses of a rural community if their petrol station closes, entailing a long round trip to obtain fuel. One in ten people in Scotland live in rural areas, and data compiled by the Scottish Forum for Transport and the Environment suggests that the average miles travelled per person per year is 85% more in rural regions than urban areas. In addition, levels of car ownership in rural areas are higher than the EU average, while incomes are lower. The price of fuel in remoter areas is also higher. Consequently, companies located in rural Scotland have relatively high transportation costs relative to competitors within the UK, and in continental Europe.

5.10 Many organisations favour incentives for influencing individual and organisational behaviour, as opposed to punitive taxes. Differentiation of charges based on marginal social and environmental costs and rates of return is perceived as an economically efficient means of achieving emission reductions. Greater allocation of revenue raised by transport taxation for maintaining the transport infrastructure would reduce the negative impression of fuel duty as a revenue raising measure. Several urban schemes hold promise, including the Park and Ride Development (Aberdeen), Rapid Transit Bus and Route Action Plans (Glasgow), Greenways (Edinburgh) and the Crossrail Project (Edinburgh). The private sector is also involved in initiatives to reduce fuel and vehicle use. A grant from Government contributed to Safeway's recent decision to move supermarket goods intended for the Highlands market by train from Glasgow to Inverness. It is reported that this project alone will save 10,000 lorry journeys each year. Other supermarkets such as Tesco are re-designing their distribution systems so as to reduce lorry journeys by means of regional hubs, consolidated loading, and more local sourcing of goods. Small and medium enterprises (SMEs) may benefit from innovative support schemes, paid out of the fuel levy. For instance, special

grants could be provided to encourage engine replacement in older vehicles, thereby enhancing fuel efficiency and reducing costs.

5.11 EU initiatives to reduce vehicle emissions include agreements with car manufacturers and encouraging the development of new fuel-efficient engines. In the medium term, hybrid electric-petrol or electric-diesel engines appear to offer the most promise for reducing emissions per km of use. Fuel cells powered by hydrogen are an exciting future prospect, which could be tested out in remote areas such as the Highlands and Islands, possibly using renewable energy to produce the hydrogen required.

BUSINESS

5.12 The measures to reduce emissions from business depend on taxation, emissions trading, regulation and voluntary agreements, which have been discussed in some depth by the Marshall report (1998).

5.13 The Chancellor's recent, announcement of a climate change levy on energy consumption, to be introduced in 2001, is potentially the most far-reaching climate change policy to date. The Government is proposing to tax energy regardless of its source; energy sources with low or zero carbon content are not given preferential treatment. Energy utilities and large energy users are of the opinion that a preferential tax regime for renewables would act as a major boost to the sector. On the positive side, however, energy taxation is relatively straightforward to implement. The costs to companies of the energy tax are not clear, though companies estimate an additional 10 to 60% on the energy bill. Off-setting the tax against national insurance contributions will benefit certain types of firms more than others; energy-intensive firms with a small labour force will be hit hardest. In addition, many small enterprises consist of a self-employed individual, who cannot recover extra energy costs through reduced NI contributions.

5.14 The Chancellor also announced in March 1999 that a test-run of greenhouse gas emissions trading would be encouraged. This is a mechanism whereby a company (or sub-unit) can exchange ('buy') any unused emission consent of another company in place of making real reductions in its own emissions. There is a general perception amongst business that trading provides more flexibility for effective responses to reducing emissions than taxation. Trading schemes are seen by many to accord well with the entrepreneurial spirit of commerce. They could, however, be very complex to implement. Scotland has about 200 large companies and nearly 300,000 small to medium size enterprises (SMEs). There are several proposals for simplifying the establishment of a carbon trading system; for example, by inviting industry organisations to co-ordinate its member companies. The offshore sector is actively engaged in developing emissions-trading schemes. BP Amoco, for instance, operates a company-wide pilot emissions-trading scheme (the first such scheme in the world). Trading takes place between business units, depending on the relative marginal abatement costs of the activities. Although in its infancy, strategic decision-making now considers criteria for carbon dioxide emissions reductions.

5.15 Many energy intensive firms have already devoted considerable efforts to increasing energy efficiency. Nevertheless the use of more efficient sources of energy such as combined heat and power (CHP) is still an option for many firms. SMEs have little leeway for absorbing increasing energy costs and could be adversely affected. Often the time and

personnel resources required for implementing energy audits and efficiency improvements are not available. And as with the domestic sector, the most energy inefficient SMEs are likely to be the least well-off and less able to act. The Scottish Executive provides a high level of support and advice on energy efficiency but has not yet attracted substantial interest from the SME sector. The Government may need to establish grants in order to encourage further uptake of CHP amongst larger firms and energy efficiency measures in the SME sector. Most respondents endorsed the general principle of providing incentives. For instance, grants could be made available to replace older boilers and older vehicles, to install cavity wall and loft insulation, and to provide advice.

DOMESTIC

5.16 The means of reducing emissions from the domestic sector include tackling poor thermal efficiency of housing (and the related fuel poverty), financial incentives and better information, and enforcing energy efficiency standards for domestic appliances.

5.17 High fuel consumption in Scottish housing reflects the low level of thermal efficiency and the cold climate. Less than one in three homes have the combination of central heating, adequate insulation and double-glazing. Over nine out of ten homes were built before the introduction of improved energy efficiency standards. The average 'National Home Energy Rating (NHER) of buildings built after 1982 is over 5, compared with a value of approximately 4 for those built earlier. While many new houses are being built to higher thermal standards, the turnover of stock is low and the thermal efficiency of existing housing needs to be improved.

5.18 The need to encourage households to improve energy efficiency requires a combination of incentives and information. Taxation remains a blunt instrument for enforcing a change in behaviour. Information could include, for example, the use of energy rating measures when buying and selling houses. Incentives will require a tangible financial gain to be successful. Information resources are available already in the form of organisations such as the Energy Saving Trust, but market penetration remains small. Further funding in this area may be required along with further support for the implementation of the Home Energy Conservation Act.

5.19 Much of the electrical equipment used in homes is extremely inefficient. Work is required, probably at the EU level, to influence the development of higher standards of efficiency in equipment by manufacturers. Energy labelling on its own appears to have little effect. Schemes for replacing energy bulbs and fridges with low energy alternatives in Edinburgh, by Lothian and Edinburgh Environmental Partnership, are examples of financial incentives assisting with energy efficiency gains.

LAND USE

5.20 The Kyoto Protocol on Climate Change commits developed countries to protect and enhance greenhouse gas reservoirs and sinks. Forests, soil, and other vegetation are an important part of the reservoir, or pool, of carbon. Changes in the size of the pool can constitute a significant sink or source for carbon dioxide. Land use influences the amount of carbon stored in soils; change in use can result in sinks or sources of atmospheric carbon

dioxide. At present only changes in woody biomass occurring between 1990 and 2012 will be included under the Kyoto protocol for all signatories. The UK greenhouse gas inventory will also include changes in soil carbon. This process and other factors, such as changes in the amount of carbon stored in timber products, are still under discussion.

5.21 Expanding forest areas and allowing agricultural land to revert to a more natural state causes carbon stocks to increase. Conversely, cultivating moorland will increase carbon dioxide emission. Recent increased use of land for forestry, agriculture and unmanaged and uncultivated urban development has been causing soil carbon to fall. However, agriculture changes, in the form of set aside policies and the shift away from intensive practices, is reversing this trend. Agriculture is likely to continue to be driven by a range of agri-environment and farming support policies. At present land use change and forestry is a net source of carbon in the UK, but is likely to become a net sink in the near future. Both forest expansion and change in agricultural practice are relatively more important in Scotland than the rest of the UK; under a devolved administration, any targets for greenhouse gas emissions will need to consider these processes.

5.22 The public and private forest industry obviously can contribute to the reduction of excess carbon dioxide by planting more trees. There is a range of views on how best to implement such a policy. The difficulty reflects the area of land that could be planted with fast growing species such as Sitka spruce, without objections from the public, land-owners or pressure groups. An alternative and perhaps more effective strategy is to use woody biomass as fuel in small local CHP schemes. These could use wood from a wide range of species, including trimmings from normal forest operations and trees from specially grown energy plantations. Forestry initiatives have the potential to encourage diverse woodlands to provide a range of products; hardwoods for craft, fuel wood for the power stations, and increased recreation in the more extensive broad-leaved woods of a warmer climate. In addition, timber can be substituted for high-energy products such as bricks and cement blocks. Increasing the numbers of timber houses aids strategies for reducing emissions and improves home energy efficiency.

5.23 Encouraging such emission reduction strategies would require new initiatives to fund and encourage investment for growing new forests and to develop policies for trading carbon offsets, where emissions from one source are offset against absorption by another. It is clear that woodland owners and investors require additional finance and new mechanisms to direct investments into appropriate forestry schemes. Existing Woodland Grants and State forestry schemes are generally effective. There is less agreement on how such schemes might be used to encourage carbon dioxide reduction policies. The simplest approach, and one favoured by many in the forest industry, is of increasing the availability of existing grant schemes for planting and by greater expenditure by Forest Enterprise. Although offsetting carbon dioxide emissions by investing in forestry already occurs, trading of carbon offsets needs to be closely regulated to achieve the desired objectives.

CHAPTER SIX SCOTTISH IMPLICATIONS OF CLIMATE CHANGE: OPTIONS FOR FUTURE WORK

6.1 This chapter aims to synthesise the information presented in the preceding chapters and reflect on the implications for the Scottish response to climate change. Annex 3 provides a table summarising the socio-economic drivers for change and the climate impacts in each sector.

6.2 The UK Climate Impacts Programme climate scenarios suggest Scotland will have the following seasonal characteristics over the next century:

- Spring: warmer, drier (until the 2050s) with more year to year variation in rainfall and lower average wind speeds
- Summer: warmer, with little marked change in rainfall or average wind speeds
- Autumn: warmer, much wetter and higher average wind speeds
- Winter: more pronounced warming, wetter, but with lower mean wind speeds and less year to year variation in temperature or precipitation

The probability of intense rainfall events leading to flooding is likely to increase, becoming perhaps several more times frequent than at present. There are likely to be more frequent days with higher summer wind speeds. According to the scenarios, there will be little average change in cloud cover and so little change in the incoming levels of solar radiation. The climate scenarios show no clear trend for increases or decreases in gales, though the numbers of very severe gales rises slightly. Changes in average sea level will range from close to the present situation to over 0.6 m higher by 2050.

6.3 Across the various socio-economic sectors it is clear that an average seasonal temperature rise, particularly in winter, is more beneficial than detrimental. Reduced energy costs from a warmer, less windy and less variable winter are likely to offset any extra costs in the domestic and business sector required for extra cooling in the summer. There will be less disruption to public services and transport in winter if icing problems are less common. Public health is likely to benefit more from winter warming than be damaged by the effect of extremes of summer temperature. Similarly, use of shared public space, which is crucial for sustainable cities, is likely to benefit from the average seasonal temperature rises. Agriculture and forestry benefit from increased rates of growth, though this could be balanced by further migration of pests and diseases from the south of Britain. Exceptions to these benefits do occur of course, such as the detrimental impact on health of an increase in photochemical smog resulting from warmer, less windy periods.

6.4 Average seasonal precipitation increases are generally beneficial in specific eastern parts of Scotland, because of the increased abstraction needs of agriculture and horticulture, but less welcome in the west of Scotland. Water resources, however, are critically dependent on seasonal and regional variations in rainfall. The climate scenarios cannot shed light on regional variations across Scotland, which have recently led to wetter weather in the west and a drier regime in the east of Scotland. Seasonal differences in the rainfall, particularly if much of it falls in autumn and winter, it is likely to be detrimental to the water resources industry, since reservoirs will already be full. Excess surface water run-off might require further developments in the waste and floodwater infrastructure. With drier spring months, the tourist season may lengthen though the link between good weather and tourism remains unclear. Increased rainfall is detrimental to the housing sector, by increasing the already

significant problems of damp and attendant health problems, though this may be offset by warmer temperatures.

6.5 Any greater variability of precipitation, particularly in the frequencies of intense rainfall events, is extremely detrimental to all sectors. Consequential flood damage to infrastructure would be common. Those most vulnerable appear to be organisations with responsibilities for maintaining services over a wide geographical area, such as transport organisations and public authorities. Other specific problems arise from the location of infrastructure, business or domestic, in areas of risk to river flooding such as on flood plains. The management of floodwater is a problem for many organisations, ranging from large companies to individual households. Redesigning waste and floodwater systems to cope with an increased frequency of intense rainfall events is likely to be extremely expensive and requires forward planning. An increased role for planning, as envisaged in the National Planning Policy Guidelines 7: Flooding and Planning (1998), for future development on areas at risk, would appear to be important. Continued improvement of links between builders, planners and the insurance industry would appear to be beneficial for future development.

6.6 Sea level rise provides few benefits for society or ecosystems. On rocky coasts the effect is likely to be minimal. Soft coasts comprising sand dunes and estuarine mudflats may migrate inland, if allowed by human activities, or reduce in size. Economically, sea level rise will affect primarily the transport sector. Infrastructure changes may be required at larger ports to minimise disruption at high tide to commercial traffic. There are only a few dwellings in Scotland at risk from a 0.5m sea-level rise, but for these there will be a profound impact. The worst coastal flooding usually occurs when there is a conjunction of high tides and storms and this will be exacerbated by sea-level rise.

6.7 Mean wind speed is a less meaningful indictor than a measure of extremes, such as the frequency of storms, which are detrimental to all sectors. Recent evidence suggests that gales over Great Britain have increased in frequency and severity in recent years. The climate scenarios suggest that overall numbers of gales might reduce but there will be a small increase in very severe gales. The rise and fall in suggested gale frequencies over the next century indicates that a clear human-induced signal is difficult to detect. Since most sectors are extremely sensitive to increased frequency of storms, further information is vital.

6.8 Measures to reduce emission of greenhouse gases in Scotland include taxation, regulation, financial incentives and voluntary agreements. There was disagreement amongst respondents as to the appropriate balance between these measures. However, most favoured incentives for influencing individual and organisational behaviour, rather than punitive taxes.

OPTIONS FOR FUTURE WORK

6.9 This scoping study suggests that there are two priorities for future work. The first is the clear need for higher resolution climate data and impact studies in Scotland. This requires work through both the UK Climate Impacts Programme, on improved climate scenarios, and by the initiation or integration of baseline studies of climate change in Scotland:

- A project funded by the Scottish and Northern Ireland Forum for Environmental Research (SNIFFER) has already been established to develop temperature indices for Scotland and Northern Ireland.
- The recently published set of climate change indicators for the UK should be evaluated for their relevance to Scotland.
- The creation of a 'meta-data' depository, which identifies climate data held by different organisations, would be a useful tool for climate impact assessments. This information needs to include key indicators of climate that are of interest to users, such as an index of storminess and of rainfall intensity.
- Maps are required of the exposure of geographical areas to future climate impacts, such as flooding, storminess and sea-level rise
- Data of changing patterns of precipitation and snowfall across Scotland are vital, along with improved modelling of future changes
- A full analysis of the relative impact of climate change on different regions of Scotland
- A comparison of expected climate impacts and planned mitigation and adaptation strategies with similar countries, such as Norway, Sweden and Ireland.

6.10 The second priority is for exploring the linkages between the main driving forces on each sector, the likely impacts of emissions strategies, and climate impacts. Climate impacts are not the most important driver on any one sector and are unlikely to become so in future. Effective adaptation to climate change requires identification of potential 'win-win' situations where emissions reductions and/or means of adapting to climate impacts occur in conjunction with policies affecting the drivers of change in the sector. This requires more information on:

- Public perceptions of climate change issues and uptake of measures to reduce greenhouse gas emissions prior to visible signs of detrimental climate impacts
- Effect of land use strategies, such as afforestation, on Scotland’s greenhouse gas emissions
- Links between likely future changes in different sectors and the requirements of the sector to reduce greenhouse gas emissions
- Business opportunities associated with climate change issues

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ANNEX 1 LIST OF EXPERT RESPONDENTS

Name	Organisation
ENERGY	
Chris Anastasi	British Energy
Fred Dinning	Scottish Power
Peter Donaldson & Bill McGregor	Scottish & Southern Electric
Kevin Dunion	Friends of the Earth Scotland
Paul Hyde	Amerada Hess
Fran Marks	Shell Exploration
Paul Mitchell	Aberdeen University
Jeremy Sainsbury	Scottish Renewables
Steven Salter	University of Edinburgh
Malcolm Wells & David Odling	UK Offshore Operators Association
Bert Whittington	University of Edinburgh
TRANSPORT	
Glyn Alesson	First Group
Doug Brown	Grangemouth Harbour Master
Ken Durdon	Caledonian McBrayne
Operations Engineer	Aberdeen Harbour Authority
Neil Greg	AA Scotland
Susan Shaw & Janette Anderson	Rail Track Scotland
David Sinclair	Forth Ports
Roddy Yarr	Scottish Airports Ltd
BUSINESS	
Gordon Adams	Consultant
David Adams & John Parks	SmithKline Beecham
Jim Allison	Scottish Tourist Board
Blair Armstrong	Scottish Enterprise
Greg Campbell	CBI Scotland
Scott Crossett	Scottish Environmental Industry Association
Mark Dodsworthy	Astra Zeneca
Ian Findlay	Highlands & Islands Enterprise
Graham Hamilton & Derek Forest	BP Chemicals and Oil, Grangemouth
Alan Jessman	NEC Semiconductors
David Lake	Digital / Compaq
George Marston	Tesco
Steve Milne	Walkers Shortbread
Richard Naylor & David Gibb	Scottish & Newcastle
Colin Pritchard	Institute of Chemical Engineering
Ross Purves	University of Edinburgh
Mark Rhodes	GlaxoWellcome
Edward Riley	Caledonian Paper
Neil Smith	Baxters of Speyside
Phil Stubbs	Boots the Chemist
Mark Wilbourn	Babcock Rosyth
Christine Wood	Tullie Russel Paper Manufacturers
Eric Young	Diageo
PUBLIC SERVICES	
Raymond Agus	University of Edinburgh
Bill Byers	East of Scotland Water Authority
Anthony Carson	Borders Council
Tim Clark	Aberdeen Coast Guard

Name	Organisation
Mike Cressey	University of Edinburgh
Richard Crowther	Regional Inspector, Coast Guard
Deborah Donnet	Glasgow City Council
Nick Hanley	University of Edinburgh
Neil Hemings	North of Scotland Water Authority
Helen Irvine	Scottish Centre for Infection and Environmental Health
Wolgang Rudig	University of Strathclyde
Adrian Shaw	Agyll & Bute Council
David Stevenson	West of Scotland Water Authority
DOMESTIC	
Stephen Garvin	BRE Scottish Laboratory
Eoin Lees	Energy Savings Trust
Alan Mackie	Scottish Office
Graham Purvis	National House Builders Council
Archie Stoddart	EST Scotland
Ian Walker	Scottish Homes
Andrew Warren	Association for the Conservation of Energy & British Energy Efficiency Federation
AGRICULTURE, FORESTRY AND FISHERIES	
Melvin Cannell	ITE Edinburgh
William Crowe	Scottish Salmon Growers Association
Barry Gardiner & Mark Broadmeadow	Forestry Commission Research
John Grace	University of Edinburgh
Jonathan Hall	Scottish Landowners Federation
Mike Heath	Fisheries Research Services
David Henderson-Howard	Forestry Commission Scotland
Paul Jarvis	University of Edinburgh
Peter Maitland	Fish Conservation Centre
Hamish Morrison	Scottish Fishermens Federation
David Oglethorpe	Scottish Agricultural College
Richard Shelton	Fisheries Research Services
Graham Shimmield	Dunstaffnage Marine Laboratory
Richard Tipper	University of Edinburgh
Bill Turrell	Fisheries Research Services
Andrew Wallace	Association of District Salmon Fishery Boards
ENVIRONMENT	
Tony Bailey-Watts	IFE Edinburgh
Ian Bainbridge	RSPB
Bill Band	SNH
Richard Bateman	Royal Botanic Gardens
Mike Billet	Aberdeen University
Noranne Ellis	SNH
David Fowler	ITE Edinburgh
Glen George & Colin Reynolds	IFE Windermere
Mike Hulme	Climate Research Unit, University of East Anglia
Gareth Jones	University of Strathclyde
Darren Kindleysides	RSPB
Ed Paterson	Macaulay Land Use Research Institute
Nick Reynard	IH Wallingford
Ian Shennan	University of Durham
Keith Smith	University of Edinburgh
Alan Werrity	Dundee University

ANNEX 2 INFORMATION PROVIDED TO EXPERT RESPONDENTS

Background

Scotland's climate will continue to change in the coming century. Reducing the uncertainties in our knowledge of future climate change and its impacts is the objective of various research projects in the UK and elsewhere. There has, however, been little work on how businesses and other organisations might adapt to the potential impacts of climate change. In response to the possible adverse impacts of climate change on human society, the UK and other developed countries agreed, at Kyoto in 1997, legally binding targets to reduce emissions of carbon dioxide (and other gases with similar properties). These gas emissions are thought to be the prime human influence on global climate. As a result of a burden-sharing agreement within the EU the UK is obliged to reduce carbon dioxide emissions by 12.5% by 2008-2012; the UK government has voluntarily extended this target to a 20% reduction by 2010. We can anticipate further tightening of emission targets after this time. The first step towards developing a UK strategy for combating climate change was the government's Climate Change Consultation Paper, published last year, which set out the policy framework and possible options for action. The most likely areas to be targeted by mitigation strategies are: transport, power generation, business energy use, energy efficiency in the domestic sector, and land use (particularly agriculture and forestry).

Although the emission targets have been agreed for the UK as a whole, some of the responsibilities for achieving them lie with devolved administrations, including the Scottish Parliament. In order to develop a Scottish strategy for combating climate change, the Scottish Office have commissioned this scoping study to provide the necessary information. This study will build on the outputs of the two workshops hosted by the Scottish Office last year on climate impacts and mitigation strategies.

Research Objectives

The key objectives of the project are to:

1. Review the existing research on climate change issues, particularly the impacts of climate change

2. Define and prioritise future research, and identify areas where policy and/or legislation are required to ensure Scotland meets its obligations for mitigating the causes of climate change

3. Consider ways in which Scottish organisations and business might adapt to climate change

4. Consider public awareness of climate change issues.

Research Approach

The scoping study encompasses three stages:

1. **Literature and policy review of climate change issues**
   Identification of the key experts and stakeholders across social, economic and environmental sectors in Scotland. Development of an appropriate framework of questions on the critical issues, to ask the experts and stakeholders.

2. **Interviews with experts and stakeholders**
   Interviews with about 100 people, either face-to-face or by telephone, to obtain information on projected climate change impacts, mitigation and adaptation strategies for each sector.

3. **Analysis of the information and production of report**
   The responses of the experts and stakeholders will be analysed to detect the vulnerability or sensitivity of each sector to climate change impacts, combined with a judgement on the confidence of predictions. Production of final report for the Scottish Office.

Issues Covered in the Discussion

We wish to obtain information for your sector in two broad areas. Firstly, we seek to identify the potential impacts of climate change on your sector and the possible compensatory adaptations. Secondly, we need to understand the effect of potential mitigation strategies to reduce greenhouse gas emissions, imposed by the Government on the sector, and possible means by which your sector might cope with or benefit from such strategies.

1. Climate change impacts and adaptations:
It is apparent that the environment, economy and society will continue to evolve during the next century, whether there is climate change or not. It follows that we are not interested in the absolute change of a particular sector; we are interested in the additional sensitivity or vulnerability of the sector associated with climate change. Consequently, we will ask you to assess the relative importance of projected climate change compared with likely future socio-economic changes in your sector. We will also ask you which components of climate most affect your sector (e.g. temperature, precipitation, wind speeds); climate change predictions are more certain for some climate components than others. The inherent uncertainty in the climate change projections complicates any decision making process. We will ask you to describe your sector's possible options for adaptation to climate change, consider whether incremental adjustments might suffice or if major strategic policy changes are required, and estimate what the costs and benefits might be.

2. Climate change mitigation strategies:
The Government wishes to encourage a move to a low carbon economy, which maximises the opportunities and benefits presented by climate change without impairing competitiveness. It is likely that policies, imposed by the Government to attain the UK greenhouse gas emissions target, will have as much effect on each sector as the direct impacts of climate change in the next few years. We will ask you how your sector might reduce greenhouse gas emissions (e.g. energy efficiency, changing standards, voluntary agreements,

legislation), how it might cope with imposed emissions targets, and whether there are mechanisms to limit the cost of such impositions on your sector (e.g. carbon trading).

The questions we will ask during the interview will be similar to those below, though clearly not all questions are relevant to all environmental, social and economic sectors:

Climate Impacts:

- What are the key socio-economic drivers and pressures on your sector?
- What are the attributes of your particular sector that may be affected by climate change?
- On what time and space scales is climate likely to have an impact?
- What is the sensitivity of your sector to specific elements of climate change?
- What are the opportunities and benefits presented by climate change for the sector?
- Why does the potential impact matter and to whom does it matter?
- Can the attributes in your sector that are sensitive to the climate be substituted with other attributes?
- What are the key uncertainties in your assessment of climate change impacts on the sector and what data would be required for greater certainty?

Climate Change Adaptation:

- What adaptation strategies can you envisage that would moderate the impact of climate change on your sector in the short, medium and long term?
- What are the likely costs of such responses?
- What are the other environmental and social impacts of such responses?
- What are the barriers to the uptake of such responses: technical, economic, social, cultural, political and institutional? How might such barriers be overcome?
- What are the key uncertainties?
- What are the resulting management implications for the sector?
- What will be the public perception of changes to the sector?

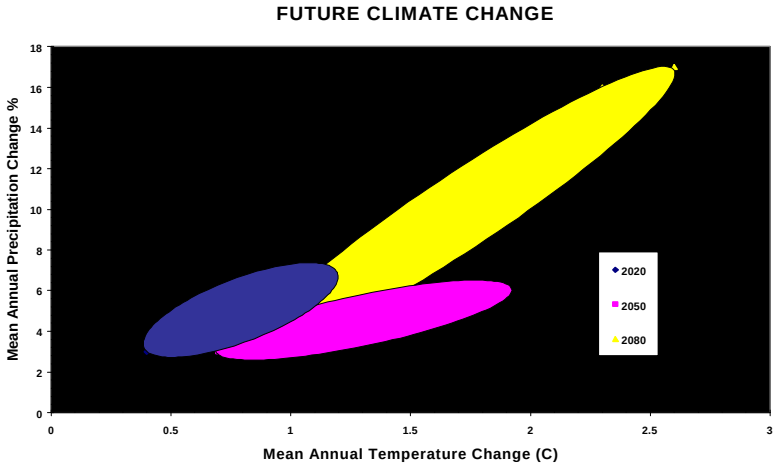
Climate Change Mitigation:

- What approaches could be used to reduce the emissions of greenhouse gases from your sector?
- What is the likely cost?
- How will Government mitigation strategies affect the sector: e.g. taxes, regulatory framework?
- What opportunities are available to maximise the benefits of proposed strategies e.g. carbon trading?
- How do you think devolution might affect your sector?

UK Climate Change Scenarios

The UK Climate Impacts Programme, funded by the Department of Environment, Transport and the Regions, has produced a set of scenarios of UK climate change in the next century. While there remain many uncertainties in predicting national or regional climate change, these scenarios are based on the best information available in 1998. Further information on these scenarios can be obtained from the UKCIP, Environmental Change Unit, 1a Mansfield Road, Oxford OX1 3TB. Tel: 01865 281192; Fax: 01865 281188; Email: ukcip@ ecu.ox.ac.uk; Internet: http://www.ecu.ox.ac.uk/ukcip.htm.

We summarise a few of the key aspects of the UKCIP scenarios in the form of a chart of likely changes, from the baseline of 1961-1990, in annual temperature and precipitation for the years: 2020, 2050, and 2080. The scenarios suggest that future change in annual temperature and precipitation for Scotland will be in the ranges marked by the filled areas below:



SUMMARY

Temperature

- Relatively more warming in winter than in summer
- More warming in east than west, due to the moderating influence of the Atlantic Ocean in the west
- Warming by between 0.1 and 0.3°C per decade

Precipitation:

- Wetter in autumn and winter, and probably wetter in west and drier in east
- More intense rainfall events
- Modest increases in overall annual precipitation under many scenarios

Wind:

- Summer gales more common, winter gales less often but more intense

Sea level:

- 2-63 cm increase in sea level in west Scotland
- 8-69 cm increase in sea level in east Scotland

ANNEX 3 SOCIO-ECONOMIC DRIVERS FOR CHANGE AND CLIMATE IMPACTS IN EACH SECTOR

Socio-economic Drivers	Climate Impacts	Temperature	Rainfall	Wind	Sea-level	Variability	Other
Energy supply							
• Market factors • Environmental legislation • Historical structure • Subsidies • Regulation	Flood damage to coastal installations				✖		
	Faster growth of biomass plantations	✓	✓				
	Increased potential for wave and wind power			✓		✖	
Transport							
• Integrated transport policy • Road congestion • Urban pollution • Market • Lifestyles	Flooding of roads and railways by rivers, increased probability of landslides		✖				
	Increased amount of fallen leaves on railway tracks		✖	✖			
	Increased disruption of operations in vulnerable harbours			✖	✖		
	Reduced road delays and damage from snow, frost and icing	✓					
Domestic							
• Quality of existing housing • Fuel poverty • Economic and demographic change • Building regulations • Health concerns • Social exclusion	Increased damp problems		✖	✖			
	Flooding in low-lying coastal areas		✖	✖	✖		
	Flooding close to rivers		✖				
	Reduced energy need for winter heating	✓					
Public services							
• Provision of cost-effective and efficient services by LAs • Funding of LAs • Relationship between Scottish Parliament and LAs • Environmental regulations • Local Agenda 21 • Water quality and waste regulations • Health concerns	Increased costs and disruption of services by coastal flooding			✖	✖		
	Increased costs and disruption of services by flash flooding of rivers		✖				
	Impact of increased run-off on water quality and design of drainage		✖				
	Increased blockage of sewers and culverts and discoloration of water		✖			✖	
	Possibility of water shortage in east, though regional rainfall pattern uncertain	✖					
	Increased incidence of food poisoning and damp-related diseases	✖	✖				
	Health problems associated with climate-induced increase in air pollution	✖					
	Reduced cost of clearing snow and ice from roads	✓					
	Water resources and abstraction favoured by increase in mean rainfall		✓				
	Less cold-related morbidity and death in winter	✓					

Socio-economic Drivers	Climate Impacts	Temperature	Rainfall	Wind	Sea-level	Variability	Other
Business							
• Market forces • Environmental legislation and taxation	Increased inland and coastal flooding		✖		✖		
	Increased energy requirement for cooling manufacturing processes	✖					
	Reduced energy use for winter heating	✓					
	Tourism favoured by summer warmth and spring dryness	✓	✓				
Primary Produce							
• Decline in marine and freshwater fish stock • Growth of aquaculture industry • Fishing regulations • Rural policy and employment • Countryside access and amenity • Agricultural policy and subsidies • Public's environmental concerns • Market factors	Changes in ocean currents reducing availability of food for fish and recruitment to breeding stocks						✖
	Impact of increased flash flooding of rivers on fish habitat		✖				
	Competition from coarse fish favoured by higher temperatures and lower oxygen concentrations	✖	✖				
	Increased incidence of forest pests	✖	✖				
	Increased tree damage and blow-down			✖			
	Negative impact of increased climate variability on agriculture	✖	✖	✖		✖	
	Aquaculture favoured by higher fish growth rates	✓					
	Increased growth rates of forests and crops resulting from higher temperature and carbon dioxide concentration	✓					✓
	Wider range of tree species available to forestry	✓					
Environment							
• Pollution control regulations • Protection of biodiversity • Changing land use • Agricultural policy	Loss of sensitive rare species, particularly arctic-alpines	✖					
	Increased acidic deposition		✖				
	Increased low-level ozone in south east	✖					
	Increased incidence of algal blooms	✖	✖				
	Reduced dilution of sewage and waste water discharges, leading to eutrophication		✖		✖		
	Changes to estuarine areas, loss of saltmarshes and sand dunes				✖		

The symbols in the right-hand columns indicate the causative climate variables for each impact:
✖ = causes a negative climate impact;✓ = causes a beneficial climate impact.
Source: information generated from the research.